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<b>14. ABSTRACT</b>  The object of this work is the compilation of all the available data on the action of phosgene on man and the laboratory animals. This includes data obtained in the laboratory and in the field. The information herein contained has been obtained from American, British and French reports. The British and French reports were not all available; as a consequence only a part of the British and French work is here presented. The first part of this report deals with laboratory tests while the second part is a compilation of the various field tests conducted by the Americans and British on phosgene and mixtures. Phosgene has been designated as CG, G-52, D-Stoff, carbonyl chloride, carbon oxychloride, collongite, MD-8, L-3. A glossary of pathological terms, together with a discussion of methods of obtaining concentrations and other toxicological methods referred to in this report is given in E.A.C.D. 105.						
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A DIGEST OF REPORTS CONCERNING

THE TOXIC EFFECT

of

PHOSGENE

on

MAN AND THE LABORATORY ANIMALS.

By:

H. D. CRAIGHILL

and

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MAY, 1923

TABLE OF CONTENTS.

	<u>Page</u>
I. Introduction . . . . .	1
II. Summary . . . . .	2
III. Dogs . . . . .	12
IV. Mice . . . . .	21
V. Rats . . . . .	25
VI. Rabbits . . . . .	29
VII. Cats . . . . .	34
VIII. Goats . . . . .	37
IX. Guinea Pigs . . . . .	39
X. Monkeys . . . . .	42
XI. Man . . . . .	43
XII. Admixtures . . . . .	49
XIII. Field Tests . . . . .	55
XIV. Bibliography . . . . .	196

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I. INTRODUCTION.

The object of this work is the compilation of all the available data on the action of phosgene on man and the laboratory animals. This includes data obtained in the laboratory and in the field. The information herein contained has been obtained from American, British and French reports. The British and French reports were not all available; as a consequence only a part of the British and French work is here represented.

The first part of this report deals with laboratory tests while the second part is a compilation of the various field tests conducted by the Americans and British on phosgene and mixtures.

Phosgene has been designated as CG, C-52, D-Starr, carbonyl chloride, carbon oxychloride, collongite, MD-8, L-3.

A glossary of pathological terms, together with a discussion of methods of obtaining concentrations and other toxicological methods referred to in this report is given in E.A.C.D. 105.

## II. SUMMARY.

### A. SYMPTOMATOLOGY OF PHOSGENE POISONING:

Phosgene acts as a respiratory irritant, penetrating to the terminal air cells of the lungs. The symptoms which arise are those chiefly due to want of oxygen due to impaired functioning of the air cells. In addition, there is lachrymation, salivation and nasal discharge. After exposure, the smell of the gas remains subjectively for several hours.

The symptoms noted upon exposure to low concentrations are: Irritation of the respiratory passages, coughing, dyspnoea, constriction of the chest and lachrymation. These symptoms later decrease and disappear.

Exposure to high concentrations usually produces rapid, shallow and labored breathing, burning pain in the chest, nausea, retching and vomiting. This is followed by headache and asphyxial symptoms (respiratory paroxysms ending with gagging and frothy mucus from the mouth). There may be extreme restlessness and anxiety or semi-coma and delirium. The blood shows an increase in haemoglobin, due to increased concentration of red corpuscles. X-ray examinations shows dilatation of the right heart. Broncho-pneumonia frequently occurs on the fourth or fifth day due to secondary infection. This is accompanied by increased fever and a purulent sputum.

The gas has a curious characteristic effect upon the taste, causing the odor of tobacco smoke to be very unpleasant.

One of two common types of symptoms are frequently exhibited in cases of phosgene poisoning. The predominant type is characterized by an ashen pallor; the lips are leaden colored; respiration is rapid and shallow with indications of intense oedema of the lungs; coughing is frequent; the pulse is 130-140 per minute, weak and ruminy; and general collapse follows. In the other type there is distension of the superficial veins of the face, neck and chest. The lips and tongue are blue; breathing is deeper and more rapid. There may be a cough with expectoration of thin fluid; the pulse is 100 per minute, full and with good tension.

Symptoms of phosgene poisoning seldom occur immediately, and death may suddenly occur after an interval during which no sign of injury was observed. Very often an incapacity for exertion exists which is one of the most marked effects of the gas.

The course of the disease is largely dependant upon the activity of the patient after being gassed. Exposures to high concentrations followed by complete rest and plenty of fresh air have often led to recovery whereas exposures to lower concentrations followed by exertion have often resulted in death.

Death usually occurs within the first three days and may be very sudden. Secondary infection may cause death even after a month or more.

In the case of dogs dying acutely, the temperature rises to a maximum coincident with the increased blood concentration. The temperature then falls suddenly and the animal dies.

When dogs survive the acute period the temperature arises to a maximum but the fall is slow and it gradually returns to normal.

#### Bibliography:

B.M. XXVIII 90, 8, and 10; B.M. XIV 63; B.M. XXIII 138;  
B.M. VII 50;  
P.T. VIII A385-A391, A398; P.T. II A127;  
M.Ph. 29  
A.E.F. 48;  
G - 5;  
Ph. 20; Ph. 21; Ph. 26; Ph. 37; Ph. 53; Ph. 75; Ph. 87; Ph. 114;  
Z - 50-56; Z - 50-57; Z 50-59; Z 50-42; Z 50-44; Z 275;  
H.D.D. 46; H.D.D. 56;  
Ph. 97; Ph. 98;  
A.P.N. 344.  
Correspondence Files- CD-130.

#### B. PATHOLOGY OF PHOSGENE POISONING:

##### 1. Respiratory System:

###### a. Upper air passages.

Little affected, nasal and pharyngeal mucosa moderately hyperaemic.

b. Larynx.

Hyperaemic, necrosed and exfoliated, mucosa. Fragmentation and fracture of muscle fibers, especially of posterior cricoarytenoids and transverse arytenoids.

c. Trachea.

Congestion of blood vessels, dilation of lymphatics, oedema of mucosa. Frothy serous fluid, sometimes bloody. Constriction by intraflexion of the posterior segment where the cartilage ring is interrupted.

d. Bronchi.

(1) Large and medium sized.

Epithelial lining intact; lumina filled with muco-purulent exudate; increase in goblet cells.

(2) Small.

Appear constricted; desquamation of ciliated epithelium; a layer of newly formed flattened cells; filled with desquamated epithelial cells or occasionally with organizing mass of newly formed vascular connective tissue; fibroblastic proliferation in the walls.

e. Lungs.

(1) Death within 2 hours.

Lungs small, heavy, purple, airless, water clogged. No emphysema, thin serous fluid.

(2) Death in 24 hours.

Lungs voluminous, heavy, oedematous; congested with blood, extreme dilatation of vessels; alternating emphysema and atelectasis; frothy serous fluid with dark blood from cut surface; sometimes petechial haemorrhage on surface; terminal air cells filled at end od 12-20 hours with sero-fibrinous exudate.

(3) Death in 2 - 3 days.

Similar to first day deaths; aeration of lungs greater; less fluid; pulmonary oedema reaches maximum within first 72 hours; and may ultimately disappear.

(4) Death in 4 days.

No fluid dripping from cut surface; beginning of broncho-pneumonia and often pleurisy; pneumonia may be associated with necrotization of the walls of the bronchioles, with abscess formation in the alveoli; destruction of elastic tissue; alveolar cavity filled with epithelial cells, erythrocytes and polymorphs.

(5) Death after 10 days.

Sterile pneumonia.

(a) Pleura.

Slight fibrous thickening; dilatation of lymphatics.

(b) Pleural Cavity.

Sometimes considerable pleural effusion which may be blood stained.

2. Blood Vascular System:

(a) Heart:

(1) Changes following gassing.

First stage - dilatation  
Second stage - shrinkage  
Third stage - engorgement

(2) Gross Pathology:

Left ventricle solid.

Right ventricle - flabby and dilated, muscle yellowish.

(3) Microscopic Pathology:

Cardiac walls; Some degeneration of fibres; occasional fat vacuoles; muscle fibres granular, atrophic in places, hypertrophic in others; oedema and congestion; subendocardial hemorrhages.

Pericardium: Vessels dilated; lymphatics distended;  
slight fibrous thickening of pericardium.

(b) Blood:

First Stage - Increased volume, due to influx of fluid from  
the tissues, decrease in solids.

Second Stage - Decreased volume, due to passage of fluid  
from the lungs; increased in solids and probably increase in viscosity;  
decreased oxygen carrying capacity; thrombosis in lungs and some other  
organs.

Third Stage - Return to normal.

(c) Spleen:

Malpighian corpuscles  $\gamma$  some atrophic, others hyperplastic,  
pulp distended with red blood cells, lymphocytes, fat vacuoles mononucleate;  
Hemosiderin in pulp; excessive normoblasts in splenic sinuses; some  
increase in fibroblasts; capsule normal.

3. Alimentary Tract:

(a) Salivary Glands.

Large, clear mucous cells with nucleus displaced to side;  
filled with amorphous, shiny, mucigenous substance.

(b) Oesophagus.

Superficial layers of mucous exfoliated into wide lamella;  
in the submucosa, oedema and imbibition causing detachment from muscle;  
diffuse hyperemia.

(c) Stomach.

Some oedema and congestion of mucosa.

(d) Intestines.

Some congestion of blood vessels.

(e) Liver.

Central atrophy and degeneration of secreting cells; marked  
vascular dilatation and congestion.

4. Excretory Systems: (Kidneys)

(a) Glomeruli:

Albumin precipitated in glomerular capsule; desquamation of epithelial lining of Bowmans Capsule; epithelium sometimes granular and hyaline.

(b) Tubules:

Epithelium swollen and granular; parenchymatous and fatty degeneration; occasional hyaline casts.

(c) Interstitial tissues:

Cedematous.

5. Glands of Internal Secretion:

(a) Adrenal:

Normal.

(b) Thyroid:

Marked variation in size of acini, colloid only in large cells.

6. Eyes:

Purulent conjunctivitis.

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B.M. XXVIII- Report #8

B.M. I - Report #61

B.M. XXI-76

P.T. VIII-i - 337

H.D.B. 3

Ph. 2, A.E.F. 48-05

Ph. 194

Ph. 17, Ph. 21, Ph. 40, Ph. 46, Ph. 50, Ph. 75, Ph. 96.

Z.30-12, Z.30-34, Z.30-56, Z.85-4.

H.D.B. 46, H.D.B. 56.

C. TOXICITY:

1. Man:

Odor is perceptible at 0.0044 mg./l. - H.H.D. 5; Ph. 4.

The lowest concentration detected by mouth, throat or lower respiratory tract:

Concentration mg./l.	Time of exposure Seconds	Subjects Positive	Reference
0.015	Average 42	6/9	B.M. IX-55
0.25	Not given	Not given	P.R. V-220

Irritation of eyes, nose and throat at 0.044 mg./l. H.H.D. 5  
Ph. 1.

Maximum concentration which can be breathed without immediate distress 0.035 mg./l. 43 observers exposed - Ph. 1.

Irritation of eyes - 0.0354 mg./l. - Ph. 1

Intense irritation of eyes - 0.442 mg./l. - Ph. 1.

Conjectural figures:

Minimum effective concentration:

Concentration mg./l.	Time of Exposures Minutes	Reference
2.21	0.5	Ph. 1
0.88	5.0	Ph. 1
0.02208	30.0	H.D.D. 3

2. Lethal Concentrations:

(a) For Dogs:

Summary of Data.

Concentration mg./l.	Time Minutes	Died/Exposed	Reference
4.416	1	Not given	Ph. 189
2.208	5	" "	Ph. 189
1.6	3	" "	
1.15	7.5	4/16	B.M. XXIV-86
0.893	12	Not given	G.M. O.D. 101
0.46	15	" "	Ph. 189
0.29	30	6/8	B.M. XXIV-86
0.31-0.36	30	23/29	B.M. XXXII-57
0.4416	30	Not given	B.M. XIX-74
0.33	30	" "	Ph. 189
0.14	120	" "	B.M. XXIV-86
0.024	240	3/4	B.M. XXIV-86
		- 8 -	B.M. XXXII-57

The following points were taken from a smooth curve constructed upon the results obtained by the Americans and the British on the lethal concentration of phosgene for dogs at various times of exposure. The time times concentration value has also been calculated.

Lethal Concentration Mg./l.	Times of Exposure Minutes	Time x Concentration Minutes x Mg./l.
4.42	1	4.42
2.55	2	4.70
1.65	3	4.95
1.30	4	5.16
1.08	5	5.38
0.62	10	6.22
0.46	15	6.90
0.38	30	7.55
0.29	30	8.70
0.17	60	10.20
0.14	120	16.80
0.028	240	5.76 ?

(b) For Mice.

Conc. Mg./l.	Time in Min.	Died/Exposed	Reference
0.442	1 - 5	Not given	Ph 1
0.4	10	100%	B.T. II-A 127
0.081	30	100%	B.M. XXXI-57
0.163	60	100%	Ph 77

(c) For Rats.

Conc. Mg./l.	Time in Min.	Died/Exposed	Reference
0.88	3	Not given	CIN XXII-Pt3
0.04	30	100%	B.M. XXXII-57
0.163	60	100%	Ph 77
0.02	240	100%	B.M. XXXII-57

## (d) Rabbits:

Concentration Mg./l.	Time in Min.	Died/Exposed	Reference
0.77	10	Not given	Ph. 1
0.22	60	" "	"
0.088	30	" "	B.M. XXXII-57
0.01	240	100%	"

## (e) For Cats:

Concentration Mg./l.	Time in Min.	Died/Exposed	Reference
4.416	1	Not given	Ph. 189
2.208	2	" "	Ph. 189
0.883	5	" "	Ph. 189
1.6	3	" "	C.W.M. Vol. XXII, pt. III
0.4416	10	" "	Ph. 189
0.2208	30	" "	Ph. 189
0.22	30	" "	C.W.M. Vol. XXII, pt. III
0.22	60	" "	H.D.D. -3
0.1635	60	2/3	Ph. 77

## (f) For Goats:

Concentration Mg./l.	Time in Min.	Died/Exposed	Reference
4.416	1	Not given	Ph. 189
2.208	3	" "	Ph. 189
2.2	3	" "	C.W.M. Vol. XXII, pt. III
0.883	10	" "	Ph. 189
0.4416	30	" "	Ph. 189
0.44	30	" "	C.W.M. Vol. XXII, pt. III

## (g) For Guinea Pigs:

Concentration Mg./l.	Time in Min.	Died/Exposed	Reference
4.416	0.5	Not given	Ph. 189
2.208	1.	" "	Ph. 189
0.883	3	" "	Ph. 189
0.88	3	" "	C.W.M. Vol. XXII, pt. III
0.4416	4	" "	Ph. 189
0.2208	10	" "	Ph. 189
0.0883	20	" "	Ph. 189
0.08	30	" "	C.W.M. Vol. XXII, pt. III
0.073	30	2/2	B.M. XXXII-57
0.0918	60	3/3	Ph. 17
0.02	240	3/4	B.M. XXXII-57

(h) For Monkeys:

Concentration Ns./l.	Time in Min.	Died/Exposed	Reference
2.208	1	Not given	Ph. 189
0.883	3	" "	Ph. 189
0.441	3	" "	Ph. 189
0.44	3	" "	C.W.M.vol.XXII,pt.III
0.2208	6	" "	Ph. 189
0.0883	20	" "	Ph. 189
0.08	30	" "	C.W.M.vol.XXII,pt.III
0.041	240	2/2	B.M. XXIII-57

The foregoing tables have been compiled from a number of sources and figures from different references are not comparable. The following notes apply to the references given and may afford some idea of their value.

Ph. 189: No information is given on nature of tests. It is not known whether any attempt was made to determine accurately a lethal concentration. The report was given for the purpose of bringing out broad distinctions between animals. The time of death is not indicated.

Ph. 77: The time of death was less than 24 hours. These are experimental data. Three concentrations were used, too widely variant to establish a lethal concentration.

B.M. XXIV-86: The lethal concentration was taken as that concentration which killed 70-80% of the animals within ten days. The source of the data and method of making the tests were not given.

B.M. XXIII-57: Those are experimental data. The time of death was less than 48 hours and the tests were made in a continuous flow chamber, the concentration being determined by analysis.

B.M. VII-80: The figure given by Marshall and Hanson was decided upon by them after experiments on 25 dogs. Two dogs were used at each concentration. No details of the work are given.

C.W.M. XXII-part III: The data are taken from an English report and concentrations are given as those which were "required to kill at the given time."

PT-II-A127: The time of death was less than 48 hours. These are experimental data. Concentrations were obtained by aspiration and determined by chemical analysis.

B.M. 18: The source of the data given is not known.

### III. DOGS.

#### A. SYMPTOMATOLOGY:

The following symptoms were observed during field tests, and one laboratory test which is noted. The symptoms may be roughly divided into groups, according as they are exhibited at exposures which caused death, (1) during exposure, (2) after exposure but before eight hours, (3) after eight hours but before fifteen days, and (4) those from which the dogs recovered. In the field tests definite concentrations were not known and exposures lasted thirty minutes. In the laboratory test exposures were for thirty minutes, concentrations between 0.6 and 1.2 mg./l. causing death before eight hours and concentrations between 0.15 and 0.6 mg./l. causing deaths after eight hours.

##### 1. Dogs dying during Exposure: P.T. VIII-A 385 - A 388.

Symptoms at concentrations causing death during exposure: Three out of seven dogs exhibited marked cyanosis in addition to the symptoms given in (3).

##### 2. Dogs dying before 8 hours: P.T. VIII-A 386 - A389.

B.M. VII-50 (Laboratory Experiment)  
B.M. XVIII-90-8 (B.L. XIII-76)  
B.M. XIV-65-b

Symptoms at concentrations causing death before 8 hours: Fifteen dogs in field tests showed rapid and shallow respiration, gasping and coughing, salivation, nasal discharge, lachrymation, depression, tracheal rattles, irregular heart action.

Six dogs in laboratory test at concentrations between 0.6 and 1.2 mg./l. for thirty minutes exhibited slight lachrymation, unconsciousness, dilated pupils. No violent symptoms were observed and vomiting was rare.

##### 3. Dogs dying between 8 hours and 15 days: P.T. VIII-A386 - A389

B.M. VII-50 (Laboratory Experiment)  
B.M. XVIII-90-8 (B.L. XIII-75)

Symptoms at concentrations causing death after 8 hours and before 15 days: Twenty dogs in field tests showed depression, dyspnoea, salivation, ocular inflammation, coughing, retching, rapid and shallow breathing, conjunctivitis, vomiting.

Nineteen dogs in a laboratory test at concentrations from 0.15 to 0.6 mg./l. for thirty minutes showed lacrimation and restlessness. Nine of these died.

4. Dogs which recovered: P.T. VIII-A 386 - A 388 - A 389.  
B.M. XXVIII-90-8 (B.M. XXIX-75)

Symptoms at concentrations from which dogs recovered are given: Fourteen dogs classified as light casualties showed slight lacrimation, slight nasal discharge, moderate depression, coughing, difficult breathing.

Three dogs classified as severe casualties showed marked depression, muscular weakness, ocular inflammation, nasal discharge, coughing, shallow and labored respiration.

#### B. PATHOLOGY:

B.M. XXVIII-90-8 (B.M. XXIX-75)  
Ph. 36, 44, 46, 194.

##### 1. Lungs:

The lungs contain serous material which takes either a homogeneous or granular pink stain. Cedema is present especially in sub-pleural alveoli. In animals succumbing in 12-22 days the alveoli are small with high cubical epithelial cells and large mononuclear leucocytes. Atelectasis and emphysema are found. In the case of dogs dying after 10 days, pneumonia is the direct cause.

##### 2. Heart:

Dilatation of the right ventricle is found and occasionally of the left ventricle and auricle but usually the left heart is firm. The muscle is usually pale, occasional vegetative growth occurs on the mitral valve and amongst the chordae tendineae. The blood vessels are usually well injected; there is an occasional hemorrhage under the endocardium.

dilatation of vessels; adhesions by pericardium & supraspinous atrophy or hypertrophy of muscle or presence of fat vacuoles.

##### 3. Spleen:

The spleen is slightly enlarged. The pulp is distended with red blood cells and hemosiderin is in the pulp.

4. Alimentary Tract:

Occasionally there is a congestion of the mucosa.

5. Liver:

Dark brown patches are found around the hepatic vein which is always engorged; the portal vein is sometimes engorged. Very rarely necrosis or inflammatory reaction is found.

6. Peritoneal Cavity:

No excess fluid but engorgement of vessels is found.

7. Excretory System:

The kidney has a dark cortex. In animals succumbing in 3 to 6 days, cloudy swelling, congestion of glomeruli, and fatty degeneration are found.

C. PHYSIOLOGY:

Phosgene at a concentration of 1.43 mg./l. was bubbled through defibrinated dogs blood for five minutes. A definite darkening of the blood was produced in three minutes and at the end of five minutes there was almost complete agglutination of the red blood cells with definite haemolysis. Haemolysis was complete in 15 minutes at room temperature. The lower concentrations require longer exposures to obtain the above results.

The following stages in pulmonary oedema are observed:

(1) Increased volume due to influx of fluid, probably from tissues, resulting in a decrease of the blood solids; (2) reduced blood volume, due to passage of fluid from blood to lungs, increase in blood solids, development of pulmonary oedema. (These various stages are indicative of time and degree of pulmonary change; (3) period of readjustment - return to normal.

1. Lungs:

The water content increases progressively in the lungs. There is no noticeable change in the water content of the muscle, which indicates that muscle tissue does not give up water to the blood during the lung oedema.

2. Eyes:

At high concentrations (1 to 5 mg./l.) for 1 hour intense conjunctivitis and lacrimation occurs. The cornea is intact.

### 3. Blood:

The arterial blood pressure shows a slight rise about 2 hours after gassing. It then drops to its previous level and is maintained at this point up to the period of clinical signs of lung involvement. At this stage there is a second rise which terminates in a fall immediately before the death of the animal. The venous blood pressure shows little variation until just before death when there is a slight rise.

The blood volume is unchanged until pulmonary symptoms appear. At this time there is a decided decrease. The red blood cell count increases with the volume decrease.

There is first a decrease in the concentration of the blood accompanied by a decrease in the chloride and oxygen content. After this initial decrease there is a great increase during which the chloride and oxygen content return to normal.

The coagulation time was 8 to 10 minutes four hours after the gassing. The normal time is usually 3 to 5 minutes. No change has been observed in the alkaline reserve. No decrease in fibrinogen is established.

### 4. Cedematous Fluid:

Comparison with Plasma: The transudate resembles plasma very much and lymph still more. It contains the fundamental elements. Its percentage of water coagulable albumin, freezing point, alkalinity, percentage of chlorides, phosphates and cholesterol approach that of blood. The non-protein nitrogen, urea, ammonia and glucose are higher than in the plasma. The phosphorus and carbonate content is greater than in the blood.

### 5. Urine:

After the inhalation of phosgene there is a functional disturbance in the secretion of urine as shown by the fall of the maximum concentration of urea. This drop is considerable in the fatal cases. The urea excretion is constantly lower after severe cases of gassing which shows that the capacity for excretion has been decreased. The chloride excretion remains unchanged, the ammonia excretion is probably disturbed. In fatal cases there is always an increase in ammonia and total nitrogen. This is not the case after less severe gassing. There is an exaggerated elimination of phosphates.

References:

B.M. XXI-76  
B.M. XXXIII-136  
McPh. 28-29.  
Ph. - 46, 75, 97, 114 - App VI-b.  
Z - 30-12, 30-36, 30-39, 32-11 & 285.

D. TOXICITY:

(1) Ph. 36.

Summary of experiments on chronic phosgene poisoning.

Cone. mg./l.	Time of Exposure Minutes	Result Death in
4.410	11	10 <sup>1</sup> hrs.
4.410	12	4 "
2.884	10	9 "
2.205	30	8 <sup>1</sup> "

Criticism: Only four concentrations which were accurately known were abstracted from this report. There were not enough dogs used at any one concentration or at one time of exposure to warrant definite conclusions. H.A.K.

(2) Ph. 189.

The times of exposure necessary to produce ultimate death are given as:

Concentration mg./l.	Time of Exposure Minutes
4.410	1
2.205	3
0.882	12
0.441	30

Note: These results are given, along with lethal concentrations on other animals, only to bring out certain broad distinctions between different animals. They are not final.

(3) C.I.M. XXII-P. 1. III.

Concentration required to kill at stated time.

Concentration mg./l.	Time Minutes
2.2	3
0.88	15
0.44	30

Criticism: This is an extract from the original data and its precise meaning is not clear. H.A.K.

(4) Groesbeck and H.G. Witherspoon.  
E.A.C.D. #101.

The lethal concentrations of phosgene for dogs for  $\frac{7}{2}$  minutes exposure.

Conc. mg./l.	Deaths in 24 hours	Deaths between 24-48 hrs.	Deaths between 2-10 days	Total Deaths	Total Percent Deaths in 10 days
1.52-2.11	1/2			1/2	50
1.58-1.43	3/4		1/4	4/4	100
1.27-1.56	2/5	1/5	1/5	4/5	80
1.18-1.23	3/6	1/6	1/6	5/6	83
1.08-1.15	4/6			4/6	67
0.98-1.05	1/2			1/2	50

The lethal concentration of phosgene for a  $\frac{7}{2}$  minute exposure on dogs is placed at 1.1 mg./l. or 275 ppm.

Criticism: This work was done carefully and should be as accurate as any data available. H.A.K.

(5) Miller and Gross.

E.H. MILI-57.

Minimum lethal concentration of phosgene for dogs.

Exposure: 30 minutes.

Concentration Mg./l.	Died/Exposed	Time of Death in hrs.
0.44	2/2	12, 28
0.38	2/2	lost, 24
0.35	2/2	10, 14
0.29	6/8	5, 9, 13, 21, 22, 288
0.28	3/4	19, 19, 32
0.19	0/2	
0.18	1/2	16
0.17	1/3	12

Exposure: 4 hours.

Concentration Mg./l.	Died/Exposed	Time of death in hrs.
.054	4/4	6, 6, 6, 27
.03	3/4	9, 32, 108
.024	3/4	31, 43, 120
.019	2/4	66, 214
.016	0/4	
.008	0/5	

The lethal concentration is taken as 0.29 mg./l. for thirty minutes exposure; and 0.024 mg./l. for four hours exposure.

(6) F.F. Underhill.  
B.M. XX-74.

#### Toxicity of Phosgene on Dogs.

Time of Exposure: 30 minutes. Concentration determined by chemical analysis.

Concentration Mg./l.	No. of dogs	% Acute Deaths 1-3 days	% Delayed Deaths	% Total
0.40-0.45	29	62	3	65
0.36-0.40	30	67	13	80
0.31-0.36	29	69	10	79
0.27-0.31	30	42	12	54

(7) Marshall and Hanson.  
B.M. VII-50.

Toxicity of phosgene on dogs.

Concentration Mg./l.	Time of Death Hours
1.11	3 - 7
1.10	4
1.00	4 - 7
0.84	4 - 7
0.75	7 - 15
0.64	7 - 15
0.55	Survived
0.51	6 - 15
0.47	6 - 15
0.44	24 - 36
0.44	24
0.40	Survived
0.35	Survived
0.35	Survived
0.31	24
0.31	Survived
0.27	6 - 15
0.23	Survived
0.22	24 - 36
0.22	24
0.19	Survived
0.15	24 - 36
0.12	Survived
0.12	Survived
0.11	Survived

One dog was used in each test. 0.35 mg./l. was taken as the lethal concentration for exposure of 30 minutes.

Three dogs gassed at 0.35 and 0.4 mg./l. survived. It seems that 0.44 mg./l. would be a more reasonable figure than 0.35 mg./l. for the lethal concentration.

(8) Marshall.  
B.M. I-29.

The figures given in this report of preliminary work are included in those given in B.M. VII-50.

(9) Ph. 1.

0.276 mg./l. for 30 minutes exposure is fatal in 48 hours.

(10) Marshall.  
B.M. XXIV-86.

Preliminary report on the relation between lethal concentration and time of exposure.

<u>Concentration</u> <u>Mg./l.</u>	<u>Time of Exposure</u> <u>Minutes</u>
1.6	5
0.46	15
0.33	30
0.14	120

Criticism: The source of these figures is not indicated. The lethal concentrations are those which kill about 80% of the dogs in ten days. H.A.K.

#### IV. MICE.

##### A. SYMPTOMATOLOGY.

There is very little to be found on the symptomatology of mice. Dyspnoea is a common manifestation.

##### B. PATHOLOGY.

(1) M<sub>o</sub>Ph. I.  
Ph. 40.

###### (a) Gross Findings:

On autopsy, mice show accentuated rigor mortis, indicating lack of oxygen in the blood. The buccal, pharyngeal and laryngotraeheal mucous membranes are hyperaemic. Subepithelial hemorrhage is found.

The lungs and bronchi have a variegated aspect, large deep red areas alternating with normal. They present a bloody surface, hyperaemic on section, and vessels clogged with blood. The mucosa of the large bronchi is detached.

In the trachea the mucosa is hyperaemic, less intense, however, than in the larynx; there is constriction by introflexion of the posterior segment where the cartilage ring is interrupted.

###### (b) Microscopic Findings:

The mucus pharyngeal mucosa is moderately hyperaemic.

In the salivary and submaxillary glands, there are large, clear mucous cells with nuclei displaced to the side of the cells; the glands are filled with amorphous shiny mucilaginous substance.

In the oesophagus, superficial layers of mucosa are thrown into wide lamellae; the submucosa is oedematous. Inhibition causing detachment of muscle is found. There is diffuse hyperemia.

In the larynx the mucosa is necrosed, exfoliated and ruptured. There is a true necrotic inflammation. Fragmentation of muscle is similar to diphtheria. Fibers are fractured transversely in irregular fragments with ends split or jagged. The post cricoarytenoid and the transverse arytenoid muscles are especially affected probably from the convulsive opening and closing of the larynx.

B. PHYSIOLOGY:

(1). M.Pn. I.

Mice exposed for forty minutes to a concentration of 0.4416 mg./l. show no large quantity of gas (above 1%) absorbed into the blood. A large quantity would permanently destroy the coloring matter of the blood, but this is not the case after gassing with phosgene.

D. TOXICITY:

(1) Ph. I.

Certain gasses and vapors and their physiological effects.

Concentration Mg./l.	Time of Exposure Minutes	Effect
0.442	1 - 5	Fatal in 24 hours
0.088	15	Had little or no effect
0.055	15	Was not fatal, but oedema was produced.
0.044	6	May be fatal in 6 hrs. oedema and congestion
0.022	30	May be fatal in 48 hrs.

Criticisms: No definite decisions are reached. H.A.K.

(a) Miller and Gross.  
B.M. XXII-57.

Toxicity of phosgene on small animals.

Time of exposure: 30 minutes.

Concentration Mg./l.	Die/d/Exposed	Time of death in hours
0.21	5/5	16, 16, 16, 24, 36
0.19	5/5	16, 16, 24, 24, 24
0.15	5/5	16, 16, 16, 40, 64
0.125	5/5	24, 48, 48, 72, 120
0.12	0/5	
0.086	4/5	48, 48, 48, 96
0.081	5/5	44, 40, 120, 196, 216
0.077	2/5	44
0.075	4/5	48, 48, 48, 72
0.043	1/5	
0.040	0/5	90, 238
0.034	1/5	96, 264, 288
0.032	2/5	72, 120
0.026	0/5	

The lethal concentration for thirty minutes exposure was taken as 0.073 mg./l.

Criticism: The individual times given in the third column do not check with the data given in the second column at 0.034 mg./l. and at 0.43 mg./l. R.E.H.

Exposure: 4 Hours.

Concentration Mg./l.	Died/Exposed	Time of death in hours
0.029	5/5	18, 18, 18, 24, 40
0.020	5/5	18, 18, 72, 72, 72
0.020	5/5	18, 18, 18, 18, 18
0.010	5/5	18, 18, 18, 40, 216
0.008	5/5	48, 48, 48, 192, 192

The minimum lethal concentration was taken as 0.008 mg./l. for 4 hours exposure.

Criticism: Work should have been done at concentrations below 0.008 mg./l. to establish this point as the lethal concentration. H.A.K.

(3) Ph. 77.

Lethal Concentration if Phosgene.

Exposure: 1 hour

Deaths in 24 hours.

Concentration Mg./l.	Died/Exposed
0.433	3/3
0.163	3/3
0.081	1/3

Criticism: Data are insufficient to establish the lethal concentration. H.A.K.

(4) Kuhn and Cohn.

P.T. II, A-127.

Lethal Concentration for mice at ten minutes exposure.

<u>Concentration</u> <u>Mg./l.</u>	<u>Died/Exposed</u> <u>in 48 hrs.</u>	<u>Total percent</u> <u>died</u>
2.5	5/5	100
1.5	5/5	100
1.0	5/5	100
0.8	5/5	100
0.7	5/5	100
0.4	5/5	100
0.35	1/5	20
0.3	0/6	00
0.2	1/5	20
0.15	0/5	00

0.4 mg./l. is taken as the lethal concentration of phosgene  
for white mice at ten minutes exposure.

V. RATS.

A. SYMPTOMATOLOGY:

Ph. 58.

Slight uneasiness, salivation, lacrimation, occasional gurgling, dyspnoea, retching, clonic convulsions of hind legs and sudden collapse.

B. PATHOLOGY:

Ph. 58, 77.  
H.D.D. 45.

The lungs are usually shrunken, firm and of an elastic consistency. The upper lobes and sloping portions of the middle and lower lobes are usually dark brown-red in color with subpleural and marginal interstitial emphysema. The pleural cavity and pericardium may contain free serum.

C. TOXICITY:

(1) Ph. 189.

The times of exposure necessary to produce ultimate death, are:

<u>Concentration</u> <u>Mg./l.</u>	<u>Time of Exposure</u> <u>Minutes</u>
4.426	1/2
2.208	2
0.883	5
0.442	5
0.221	10
0.088	25

This is preliminary work.

(4) R. Mueller.

Ph. 58. (Taken from Ztscher, Exp. Path. Therap. 9,103, - 25).

Concentration Mg./l.	Time of Exposure Minutes	Result
22.00	15	Death in 4 hours 20 minutes
8.82	14	" " 1 " 7 "
2.21	5	" " 5 " 11 "
1.09	20	Recovered
1.09	8	Died over night
0.54	15	Recovered

Criticism: Only one rat was used in each test. Benzene vapor of a concentration about  $4\frac{1}{2}$  times that of the phoagene was used throughout. This makes it difficult to draw conclusions. H.A.K.

(5) C.W.M. XXII - Part III.

Concentration necessary to kill.

Concentration Mg./l.	Time of Exposure Minutes
0.88	
0.06	5

Rat exposed to a concentration of 0.27 mg./l. for 30 minutes survived 5 hours.

Criticism: This is probably an abstract from Dr. Barreroff's report given in full in Ph. 189. H.A.K.

(6) Miller and Gross.  
B.M. XXIII-57.

Lethal concentrations for rats with exposure of 30 minutes.

<u>Concentration</u> <u>Mg./l.</u>	<u>Died/Exposed</u>	<u>Time of death</u> <u>in Hours</u>
0.21	2/2	16, 16
0.19	2/2	16, 16
0.15	2/2	16, 24
0.125	2/2	20, 20
0.120	2/2	16, 16
0.086	3/4	18, 18, 18
0.081	2/2	16, 16
0.077	1/2	18
0.073	2/2	48, 48
0.043	1/2	48
0.040	2/2	18, 18
0.034	0/2	
0.032	0/2	
0.035	1/4	96

Criticism: This report is very good. The lethal concentration for 30 minutes exposure may be placed at 0.04 mg./l. M.A.K.

Exposure: Four hours.

<u>Concentration</u> <u>Mg./l.</u>	<u>Died/Exposed</u>	<u>Time of death</u> <u>in hours</u>
0.029	2/2	16, 16
0.020	4/4	18, 18, 18, 18
0.020	2/2	18, 18
0.010	0/2	
0.008	0/4	

Criticism: A concentration should have been established between 0.01 and 0.02 mg./l. M.A.K.

(5) Ph. 77

Lethal concentration of phosgene on rays t.

Number of deaths in 24 hours for one hour exposure.

<u>Concentration</u> <u>Mg./l.</u>	<u>Died/Exposed</u>
0.153	3/3
0.091	2/3

**Criticism:** The work is too limited to be of much value.  
The lowest concentration for one hour exposure  
is twice the 30 minute figure reported by  
Lt. Miller in B.M. XXXII-57. H.A.K.

## VI. RABBITS.

### A. SYMPTOMATOLOGY.

There is very little literature on the symptoms produced when rabbits are exposed to phosgene. The only symptoms noted were lachrymation and conjunctivitis.

### B. PATHOLOGY.

The pathology of rabbits dying from phosgene poisoning is practically the same as that of mice and that section should be consulted for this data.

### C. PHYSIOLOGY.

Z. 30-2; . . . . . Z. 30-44.

There is an early rise in the number of red blood cells and the amount of haemoglobin per cubic centimeter of blood within a few hours after exposure. This is due to concentration of the blood-oligemia which persists one to two days. The second stage, secondary rise, type polycythaemia may persist many weeks.

Inhalation of phosgene causes a quick fall in pulmonary ventilation and a notable diminution in the oxygen consumption and carbon dioxide production. This phenomenon lasts only with the duration of inhalation. There is a quick fall just before death. If the inhalation is not fatal, the ventilation returns to its original level. The above phenomenon is of reflex nature but not influenced by general anaesthesia. It is caused by the passage of gas into the upper respiratory passage alone and the intensity is equal to that when inhaled in the lungs also.

The following of the irritant gas into the deep respiratory passages, without passing through the upper respiratory passag does not cause diminution of ventilation. It is also on the contrary, to cause an augmentation of the ventilation. This augmentation is of a reflex nature and is not necessarily accompanied by an augmentation of the exchanges.

The last phase period or the antimortem fall of ventilation and the exchanges are not nervous reflexes but correlative with the establishment of a pulmonary lesion.

D. TOXICITY.

(1) Ph. 1.

Concentration mg./l.	Time of Exposure Minutes	Results
0.770	10	Death in 4 hours
0.520	20	Usually fatal
0.442	20	Not fatal
0.290	15	" "
0.221	30	" "
0.221	60	Fatal
0.176	30	Generally not fatal

Criticism: The lethal concentrations given by the British in Ph. 1 and Ph. 109 are considerably higher than those obtained in the U.S. E.A.K.

(2) Barcroft.  
Ph. 189.

Concentration mg./l.	Exposure in minutes to produce ultimate death.
4.416	7 - 10
2.208	7 - 10
0.883	10 - 15
0.442	30

Criticism: Report is not specific enough. E.A.K.

(3) C.I.M. XII - pt. III.

Concentration mg./l.	Time required to kill Minutes
0.83	15
0.44	30

Criticism: Data are from English reports and are insufficient for reliable conclusions. E.A.K.

(4) N.D.N. 46.

Two rabbits were exposed for 30 minutes to a concentration of 0.1472 mg./l. One died in 7 hours, the other in 5 hours.

Criticism: No minimum lethal concentration was established. H.A.K. These figures were only incidental to the main feature of the report, i.e. cause of acute oedæmia and true polycythaemis. MGW.

(5) Miller and Gross.  
B.M. XXII-57

Method - Continuous flow.  
Concentration determined by chemical analysis.  
Exposure - 30 minutes.

Concentration : Died/Exposed : Time of death  
in hours

0.21	:	2/2	:	16, 16
0.19	:	1/2	:	192
0.15	:	2/2	:	48, -?
0.123	:	2/2	:	120, 240
0.120	:	2/2	:	96, 120
0.086	:	2/4	:	192, 120
0.081	:	2/2	:	96, 96
0.077	:	2/2	:	72, 144
0.073	:	2/2	:	120, 48
0.043	:	1/2	:	144
0.040	:	2/2	:	148, 192
0.034	:	2/2	:	96, 216
0.032	:	2/2	:	72, 120
0.025	:	4/4	:	120, 168, 96, 96

0.025 mg/l. takes as minimum lethal concentration for a 30 minute exposure.

Criticism: A concentration below 0.025 mg/l should have been established and tested.. H.A.K.

Exposure: 4 Hours

<u>Concentration</u> mg/l	:	<u>Died/exposed</u>	<u>Time of death</u> in hours
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0.029	:	2/2	: 120, 120
0.020	:	3/4	: 144, 24, 120
0.020	:	1/2	: 72
0.010	:	2/2	: 72, 120
0.008	:	1/4	: 168

0.010 mg/l. taken as minimum lethal concentration  
for a 4 hour exposure.

Criticism: This is a complete accurate report.  
H.A.K.

(6) H.D.S. 3.  
Ph. 66

0.0736 mg/l. exposure for 1 hour causes death  
within 24 hours.

Criticism: This figure is three times that  
established by Miller for 30 minutes  
exposure. H.A.K.

(7) Ph. 77

Exposure 1 hour, death in 24 hours.

<u>Concentration</u> mg/l	:	<u>Died/ Exposed</u>
------------------------------	---	----------------------

0.433	:	3/5
0.1635	:	0/3
0.0918	:	0/3

Criticism: The lowest lethal figure given in this report  
is six times that given for the same exposure  
in another British Report H.D.D. 3 or Ph. 65.  
H.A.K.

III. CATS.

A. SYMPTOMATOLOGY.

Ph. 40, 58.

The only symptoms noted in the available literature are cyanosis, dyspnoea and retching.

B. PATHOLOGY.

Ph. 40, 58, 77.

There is very little available literature on the pathology of cats poisoned by phosgene. There have been found pulmonary oedema, interstitial emphysema, corroded gastric and duodenal mucosa with haemorrhagic areas.

C. PHYSIOLOGY.

H.D.D. 58.

Experiments on urine.

The acidity of urine from cats gassed at a concentration of from 0.05 - 1.7 mg./l. reaches a maximum on the 4th day after gassing. The return to normal is slow.

The coefficient of Robin falls until the 4th day, after which there is a slow and regular rise to normal.

Phosgene gives a distinctly different curve for acidity of urine than chlorine or hydrocyanic acid, with which it was compared. This suggests a possible method of diagnosis.

D. TOXICITY.

(1) Barcroft.  
Ph. 189.

Concentration mg./l.	Exposure in minutes to produce ultimate death					
		1	2	5	10	30
4.416						
2.208	1					
0.883	2					
0.442	5					
0.221	10					
	30					

Criticism: The constant relation between time and concentration for the first four concentrations is very remarkable.

H.A.K.

(2) Ph. 1.

Report upon certain gases and their physiological effects.

Concentration <u>Mg./l.</u>	Exposure <u>Minutes</u>	Result
0.380	10	Fatal in 18 hours
0.221	20	Usually fatal in 5 hours
0.110	20	May be fatal in 12 hours
0.088	20	Not fatal
0.074	30	Not fatal

Criticisms: Data are insufficient to enable drawing of conclusions. H.A.K.

(3) G.W.M. XXII part III.

Concentrations required to kill at stated time.

Concentration <u>Mg./l.</u>	Time <u>Minutes</u>
1.6	5
0.22	30

Criticisms: This is not original data. Exact meaning is not clear. R.E.M.

(4) H.D.D. 2.

Cats exposed 1 hour to concentration of 0.230% died within 12 hours.

(5) Ph. 77.

Exposure - 1 hour  
Deaths in 24 hours.

Concentration <u>Mg./l.</u>	Deaths
0.433	5/5
0.164	2/3
0.092	1/3

(6) J.H.M. 35.

3 inch shell containing 600 cc. phosgene exploded in chamber of 254 cub. m. capacity.

Theoretical concentration - 3.25 mg/l.

Three cats:

#1 on floor	died	2½ hours.
#2 1 m. from floor	"	5 "
#3 2 m. " " "	6½	"

III. GOATS.

A. SYMPTOMATOLOGY:

P.T. VIII, A 385.

Iachrysmatic depression, nasal discharge and retching were noticed during a field test, from which the goats recovered.

B. PATHOLOGY:

This is covered in a general way in the chapters on the pathology of dogs, cats and other laboratory animals.

C. PHYSIOLOGY:

Ph. 37.

The degree of oxygenation of venous and arterial blood in goats gassed with phosgene is shown in three stages; arterial and venous blood normally oxygenated, arterial blood normally oxygenated, venous blood deficient in oxygen; both arterial and venous blood deficient in oxygen.

The onset of poisoning appears not as deficient oxygenation of blood in lungs but as increased reduction of blood in capillaries.

There is evidence of obstruction to circulation in the lungs.

D<sup>2</sup>. TOXICITY:

(1) Ph. 1, 2

Concentration Mg./l.	Exposure Minutes	Results
2.21	8	Minimum fatal concentration
1.00	3	Not fatal
0.77	10	Fatal in 24 hours
0.38	10	Not fatal

(2) Barcroft.  
Pl. 189.

Concentration <u>Mg./l.</u>	Exposure to produce ultimate death <u>minutes</u>
4.416	1
2.208	5
0.883	10
0.442	50

(3) O.E.M. XXII - part III.

Concentration <u>Mg./l.</u>	Time required to kill in stated time <u>minutes</u>
2.2	5
0.44	50

Criticism: Not original data. Exact meaning not clear.  
R.E.M.

IX. GUINEA PIGS.

The (A) symptomatology, (B) pathology and (C) physiology sections are omitted here and on monkeys because of scarcity of data.

D. TOXICITY.

(1) Barcroft.  
Ph. 189.

Concentration Mg./l.	Exposure in minutes to produce ultimate death
-------------------------	---

4.416	0.5
2.208	1.
0.883	5.
0.4416	4.
0.2208	10.
0.0883	20.

Criticism: The four minute and twenty minute concentrations are apparently low. H.A.K.

(2) C.W.M. XXII - part III.

Concentration Mg./l.	Required to kill at stated time minutes
-------------------------	--

0.88	3
0.08	30

A guinea pig exposed to a concentration of 0.27 mg./l. survived four hours and thirty minutes.

Criticism: Does not state where figures were obtained. Meaning is not very clear. H.A.K.

(8) Miller and Gross.  
R.M. XXXIII-57.

Method - continuous flow.  
Concentration determined by chemical analysis.  
Exposure - 30 minutes.

Concentration mg./l.	Died/Exposed	Time of death in hours
0.21	2/2	16,-16
0.19	2/2	16,-16
0.15	2/2	16,-16
0.125	1/2	6
0.120	2/2	16,-16
0.086	3/4	18, 18,-18
0.081	2/2	18, -72
0.077	2/2	6, -24
0.073	2/2	18, -16
0.045	0/2	
0.040	0/2	
0.034	0/2	
0.032	0/2	
0.025	0/4	

0.073 mg./l. is taken as minimum lethal concentration for a 30 minute exposure.

Criticism: This is a complete report and apparently accurate. H.A.K.

Exposure: 4 hours.

Concentration mg./l.	Died/Exposed	Time of death in hours
0.029	2/2	18, -18
0.020	3/4	168, -18, -18
0.020	0/2	
0.010	0/2	
0.008	0/4	

0.020 mg./l. is taken as minimum lethal concentration for a 4 hour exposure.

Criticism: To be absolutely conclusive, 0.02 mg./l. should be tested again. H.A.K.

(4) H.D.D. 3, Ph. 2, Ph. 66.

0.2203 mg./l. exposure for one hour caused death in 12 hrs.

Criticism: The British in Ph. 189 reported the same figures for a 10 minute exposure. H.A.K.  
This is not given as the minimum lethal concentration. R.E.K.

(5) Ph. 77.

Exposure one hour, death in 24 hours.

<u>Concentration</u> <u>Mg./l.</u>	<u>Died/Exposed</u>
0.453	3/3
0.1635	3/3
0.0918	3/3

Criticism: Concentration below 0.09 mg./l. should have been tested to establish a definite minimum lethal concentration. H.A.K.

X. MONKEYS.

## A. TOXICITY:

(1) Barcroft.  
Ph. 189.

Concentration Mg./l.	Exposure in min. to produce ultimate death.
2.208	1
0.883	3
0.4416	3
0.2208	6
0.0883	20

Criticism: Sufficient data is not given to establish the lethal concentration for 3 minutes. H.A.K.

(2) D.W.M. XXII - part III

Concentration Mg./l.	To kill at stated time minutes
0.44	3
0.08	30

Criticism: Report does not state where figures were obtained. Thirty minute figure is twice that obtained by Miller. H.A.K.

(3) Miller and Gross.  
B.M. XXIII-57.Method - continuous flow  
Concentration determined by chemical analysis.  
Exposure - 30 minutes.

Concentration Mg./l.	Died/Exposed	Time of death in hours
0.061	4/4	10, -10, -10, -45
0.066	2/2	12, -16
0.041	2/2	10, -10
0.035	1/2	48
0.030	1/2	18
0.017	0/2	

0.041 Mg./l. taken as the minimum lethal concentration for a 30 minute exposure.

Criticism: A conclusive report. H.A.K.

MR. MAN.

A. SYMPTOMATOLOGY:

A.E.F. .66.  
A.E.F. 48 - G-5.  
Ph. 17, 40, 53.  
A.P.M. 34, A No. 7.

Phosgene acts as a respiratory irritant, penetrating to the terminal air cells of the lungs. The symptoms which arise are those chiefly due to want of oxygen due to impaired functioning of the air cells. In addition, there is lachrymation, salivation and nasal discharge. After exposure, the smell of the gas remains subjectively for several hours.

The symptoms noted upon exposure to low concentrations, are: Irritation of the respiratory passages, coughing, dyspnoea, constriction of the chest and lachrymation. These symptoms later decrease and disappear.

Exposure to high concentrations usually produces rapid, shallow and labored breathing, burning pain in the chest, nausea, retching and vomiting. This is followed by headache and asphyxial symptoms (respiratory paroxysms ending with gagging and frothy mucous from the mouth). There may be extreme restlessness and anxiety or semi-coma and delirium. The blood shows an increase in haemoglobin, due to increased concentration of red corpuscles. X-ray examinations shows dilatation of the right heart. Bronchio-pneumonia frequently occurs on the fourth or fifth day due to secondary infection. This is accompanied by increased fever and a purulent sputum.

The gas has a curious characteristic effect upon the taste, causing the odor of tobacco smoke to be very unpleasant.

One of two common types of symptoms are frequently exhibited in cases of phosgene poisoning. The predominant type is characteristic by an ashen pallor; the lips are leaden colored; respiration is rapid and shallow with indications of intense oedema of the lungs; coughing is frequent; the pulse is 130-140 per minute, weak and runny; and general collapse follows. In the other type there is distension of the superficial veins of the face, neck and chest. The lips and tongue are blue; breathing is deeper and more rapid. There may be a cough with expectoration of thin fluid; the pulse is 100 per minute, full and with good tension.

Symptoms of phosgene poisoning seldom occur immediately, and death may suddenly occur after an interval during which no sign of injury was observed. Very often an incapacity for exertion exists which is one of the most marked effects of the gas.

The course of the disease is largely dependent upon the activity of the patient after being gassed. Exposures to high concentrations followed by complete rest and plenty of fresh air have often led to recovery whereas exposures to lower concentrations followed by exertion have often resulted in death.

Death usually occurs within the first three days and may be very sudden. Secondary infection may cause death even after a month or more.

## 2. Ph. 21.

On general lines the symptomatology for phosgene is similar to symptomatology for chlorine, but the manner of onset is different. After an initial sensation of intense suffocation with constriction of thorax and sensation as though the heart had stopped, the man who has breathed phosgene apparently recovers completely. After 6 to 24 hours (usually 10-12) the recovery seems complete. Then suddenly, on occasion of physical effort or passing from heat to cold, or slight digestive trouble, the patient is seized by acute oedema of the lungs and dies sometimes in a few minutes. In the light cases which are in the majority, there is development of pulmonary emphysema with sensation of suffocation and increased arterial tension. These sick men neither cough nor spit. When death does not occur at once the prognosis is generally good and recovery in 8 to 10 days with about the same chance of late broncho pulmonary complications as with chlorine. The same asthenia and loss of weight occurs.

## B. PATHOLOGY:

In studying the pathological aspect of phosgene poisoning on man, it must be remembered that the data have been collected from reports on battle casualties, and that there were probably no cases of purely phosgene poisoning under battle conditions. Phosgene, in cloud attacks, was mixed with chlorine, and the two gases are, to a large degree, similar in action. The principal effects of phosgene and chlorine appear to be due to their asphyxiant action, along with local poisoning and corrosion.

Ph. 17.

An autopsy was performed on a man who died eight days after gassing. The white matter of both cerebral hemispheres was found to contain large numbers of perivascular hemorrhages, uniformly distributed. The corpus callosum contained many hemorrhages. A part of the dorsal cord showed hemorrhages in the white matter.

Ph. 20.

Hemorrhages of the white matter of the brain occur in large numbers of acute cases of gas poisoning; more frequently from phosgene than from chlorine. The breaking down of the lungs may be said to be the principal feature in poisoning by asphyxiating gases.

Criticism: This report consists of a general discussion of phosgene poisoning and does not go into details.

Ph. 40.

In this report are described the findings of a number of autopsies on soldiers dying from the effects of asphyxiating gases, but whether the gas was phosgene or chlorine or, more probably, a mixture is not stated. Congestion and oedema of the lung and respiratory system are the outstanding features, though almost all the organs may be injured.

Ab N. 66.

Post mortem findings on chlorine and phosgene poisoning.

In cases of death at 24 hours after gas poisoning, the trachea and bronchi are purple red and congested, while a thin exudate wells up into them from the lungs. The latter organs are heavy and oedematous, while aerated islets of emphysematous over distension alternate with depressed purple patches of collapse. On section, serious fluid drips abundantly from the lung tissue. Air that has escaped from ruptured vesicle is seen in chains of bubbles on the surface of the lungs, along the interlobular fissure and even penetrating the tissue of the mediastinum. In some of the earliest cases, the most intense disruptive emphysema may be observed destroying the air sacs and interfering with the circulation of their walls.

Petechial hemorrhages appear on the surface of the lungs, on the heart, and also on the inner surface of the stomach. All the veins are greatly distended and the abdominal viscera are engorged with dark red blood that clots very early after death. The heart itself may fail to show right side dilatation, for this does not of necessity appear after death in cases of asphyxiation.

If the man succumbs at a later date, inflammatory complications appear in the lungs. There is superficial pleurisy, scattered bronchopneumonia and a purulent secretion in the bronchi. The serous exudate will then be found to have disappeared and no fluid drops from the cut surface of the lungs.

#### D. PHYSIOLOGY:

Changes in the blood of rabbits, following exposure to phosgene. From Physiological Laboratories, Cambridge, England.

Experiments with rabbits exposed to a concentration of 0.1472 mg/l for 30 minutes showed that there was an early rise in the number of red blood corpuscles (acute oligoæmia). This rise persists for 1 - 2 days. There is also a secondary rise, a true polycythaemia, which may persist for many weeks.

The cause of the acute oligoæmia is the loss of water from the blood, causing a concentration of the corpuscles. By experimentation, it was found that there was an average increase of 17% in the number of red blood cells, within 3 hours after exposure to a concentration of 0.1472 mg/l. It was also determined that there was a diminution of approximately 15% in the total volume of blood. This was determined by bleeding the rabbit from the carotid.

By macroscopic and microscopic examination of the lungs, it was found that the oligaemia had a definite relationship to the amount of pulmonary oedema produced by the gassing.

Other factors contributing to oligaemia were found to be diminution in the fluid content of the blood, generalized tissue oedema due to increased osmotic pressure of the tissues caused by lack of oxygen, outflowing of fluid into the alimentary canal, and an outpouring of adrenaline.

True polycythaemia starts about the 8th day. It may persist as long as 8 weeks. In such cases, there is no pulmonary oedema. The condition indicates a definite stimulation to the bone marrow, due to the deficiency of oxygen. Experiments on convalescent animals placed in a chamber containing a high percentage of oxygen, showed that chronic polycythaemia could be temporarily abolished by exposure to the increased oxygen.

#### C. TOXICITY:

##### (1) Sherwood and Snyder, B.M. IX-38.

To determine the smallest concentration of phosgene which can be detected by mouth, throat, and lower respiratory tract.

Conc. : Total #: Posi-:Doubt-: Neg.:Doubt-: Time of Dos.  
mg/l : Tests : tive : ful Pos : ful : Tests in sec.  
: tests:tests :Tests:Neg.T-:Min.Max. Aver.

0.000:	8	:	0	:	0	:	8	:	0	:	-	-	-
0.004:	9	:	1	:	0	:	8	:	0	:	50	50	50
0.008:	10	:	2	:	3	:	3	:	2	:	35	60	41
0.015:	9	:	6	:	2	:	1	:	0	:	28	60	42
0.025:	14	:	12	:	2	:	0	:	0	:	10	60	32

(20) Ph. 4.

Experiments to determine personal factor in testing box respirators.

The subjects in the following test were familiar with gas.

Mouth breathing - Eyes protected				Nose breathing - Eyes exposed			
Breaking down : No. conc. mg./l.	Subjects tested	% of No. concn. mg./l.	Concn. mg./l.	Breaking down : No. conc. mg./l.	Subjects tested	% of No. concn. mg./l.	Concn. mg./l.
0.01766	5	8	0.01336	1	1	5	
0.0266	1	5	0.01766	5	5	14	
0.0353	17	49	0.01766	12	58		
0.04416	8	8	0.04416	1	5		
0.05503	7	30	0.05503	12	54		
0.05888	2	6	0.05888	2	6		
0.08803	2	6	0.08803	1	5		
Total - - - - -	35			Can stand stronger than 0.08803	1		5
				Total	35		

The subjects in the following test were not accustomed to gas.

Mouth breathing - Eyes protected				Nose breathing - Eyes exposed			
Breaking down : No. conc. mg./l.	Subjects tested	% of No. concn. mg./l.	Concn. mg./l.	Breaking down : No. conc. mg./l.	Subjects tested	% of No. concn. mg./l.	Concn. mg./l.
0.008802	1	12.5	0.00802	1	12.5		
0.017604	3	37.5	0.017604	1	12.5		
0.035208	2	25	0.035208	2	25		
0.04416	2	25	0.04416	1	12.5		
Total - - - - -	8		0.04416	3	37.5		
			Total - - - - -	8			

The maximum concentrations (43 persons tested) which could be breathed for 3 minutes without serious discomfort varied from 0.008632 mg./l. to 0.08832 mg./l. About one-half of the subjects found 0.0354 mg./l. to be the limiting concentration. ←

Criticism: The "breaking down concentration" is apparently the concentration which was unbearable for a period of 3 minutes, but this is not clearly indicated. R.E.M.

(3) H.D.D. 3.

A concentration of 0.044 mg./l. produced irritation of eyes, nose and throat with cough after 5 minutes; odor perceptible at 0.0044 mg./l. The conjectural figure given for minimum effective concentration is 0.88 mg./l. and for maximum safe concentration 0.02208 mg./l.

(4) Ph. 1.

Irritation of eyes produced at 0.0254 mg./l. Intense irritation at 0.422 mg./l.

Conjectural figures:

Maximum tolerable concentration

2.21 mg./l. for 0.5 minutes exposure

0.88 mg./l. for 5.0 " "

Minimum lethal concentration for a 30 minute exposure, about 0.1104 mg./l.

The maximum safe concentration for a 12 hour exposure was 0.0044 mg./l.

(5) P.R. V-220.

With eyes and nose protected the minimum concentration which can be detected by the throat and respiratory tract was found to be 0.25 mg./l.

(6) Ph. 13.

0.02208 mg./l. makes sojourn in air impossible.

(7) C.C. P. 6064 (#148).

Experiments on the "Fatigue of the sense of smell".

Eight observers exposed to a concentration of 0.00083 mg./l. for 2 min.; odor was very perceptible, only one thought intensity of odor diminished; 4 complained of irritation of eyes.

Conclusion: There is apparently no fatigue of the sense of smell in the case of phosgene.

Note: In working with phosgene in the Toxicological Laboratory at Edgewood Arsenal it has been found that phosgene does produce fatigue of the sense of smell. R.E.M.

XII. ADMIXTURES.

(1) P.T. VIII A-351.

Toxicity on dogs, Phosgene and Mustard.

A mixture of 80% mustard, 20% pure phosgene at 29°C produced death on dogs in a slightly less time than 80% mustard and 20% crude phosgene at 20°C.

Criticism: The report is vague and inconclusive.

(2) Mayer  
Z-607.

On the toxicity of a mixture of mustard gas and phosgene on dogs.

Mixture 50 cc = 72.8 gm. phosgene  
48.5 cc = 68.2 gm. mustard gas

(a) 5 dogs used at each concentration in the following tests.

Concentration Mg./l.	Exposure minutes	Resultant Deaths	Resultant deaths if mustard gas had been used separately.
0.50	15	1/3	all
0.50	5	0/3	some (1/3 for phosgene)
0.25	30	1/3	all
0.25	5	0/3	-
0.10	30	0/3	-

Note: The histological lesions on the animals used in these experiments seem less severe than those produced by pure phosgene.

(b) 1 dog used in each test.

Concentration Mg./l.	Exposure Minutes	Result
0.50	30	Died after 4 days
0.50	5	Killed after 5 days
0.50	50	Died after 5 days
0.25	50	Killed after 5 days
0.25	5	Killed after 5 days
0.10	30	Killed after 5 days

Conclusions: Mixtures of mustard gas and phosgene (50% of each) are less toxic than pure mustard gas or pure phosgene.

Criticisms: There seems to be too little data to entirely justify the conclusion. R.E.M.

(8) Martin, Searle and Dahlwig.  
B.M. XXVII-84, (12).

Mixture of mustard gas (80-85%) and phosgene (20-15%)  
Toxicity on dogs.

Method: Phosgene was displaced in flask by concentrated sulphuric acid to obtain concentration and checked by analysis. Two gases were mixed and run into gassing chamber. Ventilation of gassing chamber: 250 l/min. Mustard gas concentration calculated by loss in weight method.

Exposure: 50 minutes.

Concentration mg./l.			Delayed	Total	Recover-	%
Mustard:	Phosgene	No.	Acute	Deaths	ies in	gas
Calc:	Calc: Amt.	Dogs	Deaths	No. of	Deaths	Deaths
0.06	:0.01: 0.01	: 3	: 0	: 14, 14	: 2	: 0
0.07	:0.01:0.003 (?)	: 2	: 0	: 5	: 1	: 1
0.06	: - :4-.01	: 10	: 0	: 5, 5, 14	: 3	: 6
	: - :4-.07x			: 10		
	: - :2-.10x			: (other		
				: cause)		
0.05	:0.01:2-.006	: 8	: 0	: 11, 8, 6	: 8	: 5
0.04	:0.01:0.01	: 4	: 0	: 0	: 0	: 4

x = First runs with flowmeter. Accuracy of concentration questionable.

Conclusions:

1. Lethal concentration of mustard with 15-20% admixture of phosgene = 0.05 to 0.07 mg./l.

2. Efficiency of mustard is diminished by admixture of phosgene, as shown by the results, that there were no acute deaths and there was an increase of 6 days in average time of death over the corresponding time for pure mustard.

3. There is an apparent direct antagonism between mustard gas and phosgene.

Criticism: This checks Dr. Mayer's conclusion. H.A.K.

(4) Kruse and Ballwig.  
P. 2. VII A-348.

Toxicity on Dogs.

Mixture of mustard gas (average 75%) and phosgene, chlorine free, (average 25%).

Method: Mustard gas was aerated by the usual method. Phosgene was displaced with concentrated sulphuric acid. The gases were mixed and drawn into the gassing chamber. Ventilation of chamber 150 - 250 l./min. Chemical analysis was made for total chlorides. The mustard gas concentration was checked by subtracting the nominal phosgene concentration.

Exposure: 30 minutes.

Mustard gas conc. mg./l.	No. Dogs	Delayed Deaths Days	True Mustard Gas Deaths	Recoveries in 2 weeks	% Mustard Gas Deaths
0.17	2	4, 8	2	0	100
0.08	4	8, 6, 12, 4	4	0	100
0.07	4	5, 4, 12	5	1	75
0.06	4	10, 6, 9, 9	4	0	100
0.05	4	6	1	3	25
0.04	8	9, 8, 5	5	5	57
0.03	10	5, 4, 4, 12	5	6	50

Conclusions:

1. The lethal concentration of mustard gas with 25% phosgene is 0.05 mg./l.
2. There is no advantage from the toxicological standpoint in using the mixture.

(5) C.L. 18 (A.G. 21)

Mixtures of chlorpicrin (5 pts. approx.) and phosgene (1 pt.) were breathed (eyes exposed) by 10 subjects. Phosgene had no influence on the lachrymatory powers of chlorpicrin.

(6) Z-550, Vol. 1.  
Second Interallied Gas Conference. 5-5-18.

Phosgene and Chlorpicrin - (Phosgene 48.3; Chlorpicrin 51.7)  
Inhaled - 30 minutes.  
Mixtures not more toxic than their constituents.

(Phosgene - 50%  
German Green Gross 11 Shell (Trichloromethyl chloroformate - 30%  
(Chlorinated Arsenic - 20%)

Properties -

- (a) Sternutatory action - concentration 2 mg./l., 1 mg./l.  
0.25 mg./l. for man and animals.
- (b) Action on skin uncertain - none noted on animals.
- (c) Respiratory irritant properties - suffocant upper passages -  
concentration 0.03 mg./l., deeper passages - concentration 0.2 mg./l.
- (d) Effect of inhalation - toxicity  
Lethal conc. for dog - 0.5 mg./l. - 15 min.  
1 mg./l. - 5 min.

(7) Z-53-A

Extract from the Official Report of the Session of  
Jan. 23, 1918 - Ministry of Armament.

On the toxicity of liquids extracted from enemy shell.

Test of two enemy shell containing  
Phosgene - 48.5%  
Chlorpicrin - 51.7%

Toxicity of inhaled mixture was tested.

Method: Vaporization with compressed air in 13 cu. ft.  
chamber. Each test on 3 dogs of from 20 to 15 kg. weight.

Exposure: 30 min.

Results: Conc. mg./l.

		Died 20 hrs. after
1.0	" 24 "	"
	" 48 "	"
0.5		Died 24 hrs. after
	" 48 "	"
	" 48 "	"
0.25		Died 4 days after
		Survived
		"

Conclusions: The mixture is not more toxic than its constituents.

(8) Kruse and Dallwig.  
P.T. VIII A-353.

Toxicity on dogs.

Mixture of 50% phosgene (chlorine free)  
50% cyanogen chloride (purified)

Method: Cyanogen chloride was aerated in the usual way and immersed in an ice bath kept at 0°C. Phosgene was run into chamber by displacement with concentrated sulphuric acid. The gasses went through mixer, then into gassing chamber. Ventilation of chamber 250 L/min. Chemical Analysis: Total chlorides, cyanogen chloride. Checked by subtracting nominal phosgene figures.

Exposure time: 30 minutes.

Results:

Total Cone. mg./l.	No. Dogs	Acute Deaths Hours	Delayed Deaths Days	Total True Deaths	Recovered Days	Percent Deaths
0.90	2	20 min. 20 min.	0	2	0	100
0.41	2	7, 21	0	2	0	100
0.36	2	19, 8	0	2	0	100
0.32	4	17, 13	13*	2	0	100
0.31	2	30, 42	0	2	14	50
0.29	2	0	0	0	0	100
0.25	4	1 in 43 mins.	0	1	18, no record	0
0.23	2	0	0	0	19, 19, 19	25
0.22	2	1 in 14 hrs.	0	1	19, 19	0
0.21	2	0	13*	0	14	50
0.14	4	0	0	0	14, 14, 14, 14	0

\*Death not due to gassing.

Conclusions:

1. Lethal concentration - 0.15 mg./l. of each gas.

Note: Series with cyanogen chloride alone showed deaths at 0.15 mg./l.

2. To produce deaths with mixture, one of gases must be present in lethal concentration.

(9) Krause and Dallwig.  
P.T. VIII A-244.

Toxicity on Dogs.

Mixture of 50% Arsine  
50% Phosgene (chlorine free)

Method: Arsine was run into chamber by displacement with a saturated solution of sodium chloride; phosgene run into chamber by displacement with concentrated sulphuric acid; gases mixed before introduction into gassing chamber; ventilation of chamber 250 l./min.

Exposure: 30 minutes.

No chemical control analysis was run as the displacement method is very accurate.

A total of 20 dogs was used.

Results:

Total Conc. Mg./l.	No. Dose	Acute Deaths Hours	Delayed Deaths Days	Total Gas Deaths	Recovered in 2 Weeks	Percent Gas Deaths
0.40	4	2 Deaths 28, 9	9-1/3	4	0	100
0.39	2	0	0	0	2	0
0.37	2	0	0	0	2	0
0.36	2	1 in 18 hrs.	0	1	1	50
0.31	2	0	0	0	2	0
0.28	2	0	0	0	2	0
0.27	2	28, 46	0	2	0	100
0.21	2	0	0	0	2	0
0.20	2	0	0	0	2	0

Conclusions:

1. Lethal concentration mixture 0.4 mg./l. a little higher than either alone. (arsine = 0.3 mg./l.; phosgene 0.35 mg./l.)
2. Only advantage = more acute death.

XIII. FIELD TESTS.

1. H.A. Kuhn, P.T. VIII - A-386,  
Richter, Burnell and Oglesby, B.M. XXX-63.

Report on Phosgene fired statically in Livens projectiles.

a. Object: To determine the concentrations, limits of cloud and toxic area for dogs and goats in a double line of trenches using phosgene in Livens projectiles and to find how the concentration varies with time.

b. Method:

1. One Livens drum containing 11,980 cc. (36.67 lbs) of phosgene (90.75% pure) was fired statically 30 ft. from first trench. The distance between first and second trench was 37-1/2 feet.

2. The booster had a 1/8" groove, 3/8" wide, machined to its full length. 6 oz. black powder was used with a squib.

3. Animals used (exposure 30 minutes.)

(a) Seven goats at 20 ft. intervals with dog between goats at either end of first trench.

(b) Nine goats at 30 ft. intervals with dog between last two goats at either end of second trench.

c. Meteorological Data

October 8, 1918, 11.00 A.M.  
Weather - clear.

Wind velocity at firing, 3.5 miles per hour.  
Average for 5 minutes, 4.2 miles per hour.

Temperature of air - inside trench	56° F.
" " " - outside "	55° F.
" " ground - inside "	46° F.
" " " - outside "	47° F.

Relative humidity - inside trench	71%
" " outside "	70%

Barometer - 29.95 inches.

Direction of wind - at time of firing, right angles to center row of goats. It suddenly shifted to the right carrying most of the gas to the right of trenches. Cloud was higher in air than usual and only part of it settled in the trenches. Some phosgene was left in cup formed by bursting projectile. This boiled away in 8 minutes.

d. Toxicological Data:

First Trench

Animal	Position	Symptoms	Result
Goat	60 ft. left of center	Lachrymation, slight depression	Light casualty
"	40 " "	Lachrymation	Light casualty
"	20 " "	Lachrymation and nasal discharge	Light casualty
"	Center	Normal	No effects
"	20 ft. right of center	Lachrymation, nasal discharge, rattling	
"	40 " "	Normal	No effects
"	60 " "	Lachrymation	Light casualty
Dog	50 " left "	Slight depression, Lachrymation	Light casualty
"	50 " right "	Lachrymation, Depression	Light casualty

Second Trench

Animal	Position	Symptoms	Result
Goat	120 ft. left of center	Lachrymation	Light casualty
"	80 " "	"	" "
"	60 " "	"	" "
"	50 " "	Normal	" "
"	Center	Lachrymation, nasal discharge, depression	Light casualty
"	30 ft. right of center	Normal	Unaffected
"	60 " "	Nasal discharge	Light casualty
"	80 " "	Lachrymation, Depression	" "
"	120 " "	Lachrymation, Depression	" "
Dog	105 " left "	Lachrymation	" "
"	105 " right "	Nasal discharge, coughing, conjunctivitis	Dead in eleven days

• Field Results

Samples were taken as follows:

(a) First trench.

C - center  
D - 30 feet right of center  
E - 60 " " " "  
A - 60 " left " "  
B - 30 " " " "

(b) Second trench.

H - 20 feet left of center  
G - 60 " " " "  
F - 60 " " " "  
I - 20 " right " "  
J - 50 " " " "  
K - 80 " " " "

Sample : Concentrations in Mg./l. for the following intervals of time.

	: 5 Sec- : onds	: 10 Sec- : onds	: 30 sec- : onds	: 1 Min- : ute	: 2 Min- : utes	: 4 Min- : utes
A	0.24	0.12	1.61	5.17	0.52	0.10
B	0.62	1.71	3.91	0.75	0.10	0.24
C	0.10	0.64	2.36	0.53	0.81	0.24
D	0.12	0.21	0.45	0.25	0.24	0.12
E	0.11	0.17	0.42	0.12	0.05	0.05
F	0.17	0.49	1.39	0.85	0.32	0.21
G	-	0.11	2.55	0.25	0.11	0.05
H	0.55	0.23	1.87	0.05	0.16	0.29
I	0.21	0.52	0.53	0.64	0.76	0.99
J	0.10	0.43	0.19	0.15	0.25	0.50
K	0.06	0.20	0.18	0.06	0.58	0.18

f. Conclusions:

1. A low concentration of phosgene was produced along 120 ft. in first trench and 940 ft. in second trench.

2. The concentration produced by a Livens drum filled with phosgene fired outside of the trench under the existing weather conditions was too low to produce severe or total casualties to any extent.

3. The low concentration of phosgene in the trenches was probably due to ascending air currents and to a heavy bocstar, as most of the gas ascended and passed over the trench.

4. A higher concentration of gas could probably be produced by firing earlier in the morning before the usual increase in ground temperature.

5. Cloud too widely scattered.

6. Persistency:

10 minutes after firing - odor of phosgene pronounced in both trenches.

15 minutes after firing - odor of phosgene practically gone from trenches.

20 minutes after firing - impossible to detect phosgene.

2. Kuhn, Richter, Durrell, Clayton & Oglesby.  
P.T. VIII-A-386. R.M. XXL-64.

a. Object. To find concentration, variation in concentration, limits and lethal area of cloud of phosgene.

b. Method.

1. Time - 7.48 A.M. October 17, 1918.

2. Projectile - Livens - 11,880 cu. (36.6 lbs.)  
phosgene - 98.1% pure, placed inside 2nd trench in the old trench system.

3. Booster screwed in with litharge - glycerine cement. 6 oz. black powder used and a squib with paper peeled back. Booster grooved 1/8" long, 3/8" wide, machined to full length.

4. Animals - 5 dogs, 20 foot intervals on each side of projectile. Exposure 30 minutes.

5. Samples - 8 groups of 7 samples each taken over 5 minute periods, 4 on each side of projectile at 20, 40, 60 and 100 feet designated left to right A-H.

c. Meteorological Data.

Weather - clear.

Wind velocity at firing, 3-1/5 miles per hour.  
First 5 minutes equals 3.2 miles per hour.

Temperature of air - inside trench	45° F.
" " " - outside "	43° F.
" " ground - inside "	48.2° F.
" " " -outside "	46.4° F.

Relative Humidity - inside trench	93%
" " -outside "	92%

Barometer - 29.95 inches.

d. Toxicological Data

Animal	Position	Result
Dog	100 ft. to left	Died in 8 hours
"	80 " " "	" " 4 "
"	60 " " "	" during exposure
"	40 " " "	" " " "
"	20 " " "	" " " "
"	20 " " right	" " " "
"	40 " " "	" in 30 minutes
"	60 " " "	" " 4 hours
"	80 " " "	Recovered in 10 days
"	100 " " "	" " 5 "

e. Field Results

Sample	Gas Concentrations						
	Concentrations in mg./l. for the following time intervals.						
	: 5 Sec-	: 10 sec-	: 20 sec-	: 1 Min-	: 2 Min-	: 3 Min-	: 5 Min-
	: onds	: onds	: onds	: nute	: nutes	: ntes	: ntes
A	.00	.00	.05	--	.03	.23	.00
B	.01	.03	1.49	.93	.09	.94	---
C	.44	1.73	8.00	4.40	--	---	1.16
D	45.70	58.90	.02	.20	7.80	4.85	5.72
E	1.90	11.10	1.88	8.50	5.15	4.85	5.90
F	.60	.10	.68	.72	.15	.06	---
G	.08	.02	3.59	3.14	2.74	2.29	1.05
H	.03	.01	.03	.02	.02	.08	.22

2. Conclusions and Remarks

1. The lethal area for dogs extended 100 ft. to the left and 60 ft. to the right of the projectile.

2. Line of animals should extend farther to get the true limits of the toxic area. Possible toxic concentration beyond the point 100 ft. to left of projectile.

3. Much higher concentration of phosgene at level of dogs than at level of sample bottle (2-1/2 feet from ground).

4. Extent of visible cloud:

5 minutes after firing - 18 inches from ground, 100 feet left, 75 feet right.

10 minutes after firing - 100 feet in length.

30 minutes after firing - 45 feet in length.

5. Persistency:

30 minutes after firing - trench not habitable with masks.

1 hour after firing - no discomfort except within 20 feet of crater.

2½ hours after firing - complete disappearance of odor over crater.

J. O.W.C. 450.

Report of the Chemical Advisory Committee - March 27th -  
April 2, 1917.

a. Object: To determine the suitable bursting charge and to obtain an indication of the nature of the concentration produced by the explosion of a canister filled with phosgene, in a trench.

b. Method: 1 Livens bomb filled with phosgene with a bursting charge of 40 gm. of tetryl was exploded in trench and 32 samples of air taken.

c. Meteorological Data:

Wind velocity - 12 miles per hour.

d. Toxicological Results:

Animals used - 22 (goats, rabbits and rats) killed by gas - 15 (68%). All dead within 24 hours, many died very soon after exposure.

Casualties in clearly marked zones in trench. All animals in zone 17.5 ft. on one side and 41 ft. on the other side of bomb were killed. Partial casualties 37 ft. on one side and 67 ft. on other side.

Criticisms: Time of day and amount of phosgene used are omitted. R.E.M.

e. Field Results: Highest concentration 1 volume phosgene in 42 volumes of air, 107 mg./l., collected 20 seconds after explosion, 3 feet from bomb, 2'0" above floor.

At the bursting of the bomb very large quantities of phosgene were thrown into the air far above the ground level; despite this, high concentrations were recorded at first though a sharp drop took place about 1-1/2 minutes after the explosion.

4. O.V. A #67.

Report of O.A.C. August 7 - 18, 1917.

Experiment I.

a. Method

Four 60 pounder C.I. shell in line at 10 yards to windward of trench, exploded simultaneously, with 15 gm. tetryl bursters and #18 electric fuses.

b. Meteorological Data: Wind velocity - 5-5/4 miles per hour.

c. Field Results:

<u>Position</u>	<u>Time</u>	<u>Highest Concentration</u>
On parapet	5 seconds after explosion.	1 volume phosgene to 167 of air = 87.11 mg./l.
In trench at 3' 6" above floor	15 seconds after bursting of shell.	1 volume phosgene to 481 of air = 9.41 mg./l.
In dugout		Very low

d. Toxicological Data: Observer wearing small box respirator with extension remained in trench in direct line of the cloud. No odor or taste of phosgene was detected.

Experiment II.

a. Method: One shell exploded as above.

b. Meteorological Data: Wind velocity 4 miles per hour.

c. Field Results: Twenty-nine samples taken.

<u>Position</u>	<u>Time</u>	<u>Concentration</u>
In trench 3 ft. from shell 1' 8" above floor of shell	10 seconds after explosion	One volume of phosgene to 101 vol. of air = 44.6 mg./l.
In dugout 1' 8" above floor.	1-1/4 minutes after explo-	One volume of phosgene in 1539 vol. of air = 8.4 mg./l.

Comparison of concentrations obtained by bursting statically  
various types of missiles filled with phosgene.

Volumes of air containing 1 volume of phosgene - cu. ft./l.						
Position	(a)	(b)	(c)	(d)		
	Vol. Air, cu. ft./l.					
Parade	167	85.448	154	128.675	188	83.489
Trench	481	9.181	237	18.633	158	27.949
Down-out	56600	0.073	237	18.633	5140	0.859
			"	"	183800	0.198

- (a) 4 - 60 pr. C.I. shell exploded near a trench (See above).
- (b) 4 - 4" Stokes bombs      "      "      " (C.W.C. Report 46, pg. 6.)
- (c) 3 - 2" T.M. bombs      "      "      " ("      "      " 55, " 5.)
- (d) 10 - 4.5" C.I. Howitzer shell, Mk. I exploded near a trench  
(C.W.C. Report 66, pg. 9).

Comparison of highest concentrations of phosgene obtained by bursting one missile in trench.

Position	(a)	(b)	(c)	(d)		
	Vol. Air, cu. ft./l.					
Trench	101	145.723	125	35.539	46	96.0
Down-out	639	8.193	---	---	67	65.91

- (a) 1 - 60 pr. C.I. shell (see above).
- (b) 1 - 4" C.I. Stokes bomb (C.W.C. Report 46, pg. 6).
- (c) 1 - 2" T.M. bomb (Report 53, pg. 3).
- (d) 1 - Livens drum (Report 50, pg. 8).

#### d. Toxicological Data

Observer wearing a special box respirator with extension, entered trench immediately after explosion and remained in densest part of cloud for 5 minutes with perfect protection against the phosgene.

#### e. Conclusion

Phosgene is a suitable filling for C.I. shell.

5. G.O.P. 228 (C.W.C. 89).

Report on the front covered by the 6" (25 cwt.) Howitzer  
when firing shell filled with phosgene.

Time: January 12, 1918.

a. Method.

No. of experiment - 7  
No. howitzers used - 1; No. rounds fired - 22.  
Max range @ 4000 yards: Rate of fire B.F. - 30 seconds.  
Time taken to fire all rounds - 11 minutes.  
Howitzer on center line of section artillery trench -  
Animals over front of 60 yards.  
Shell - 6" (25 cwt.) howitzer, cast iron  
Filling - phosgene  
Bursting chg. - Furanyl C (b)  
Propellant " - 2nd N.G.T.  
Blind Shell. - 0

b. Meteorological Data

Barometer - 29.35 inches  
Thermometer - Wet bulb 37° F.  
Dry " 38° F.  
Ground temperature - 35° F.  
Wind - West, Southwest varying to West and Southwest.  
Wind Velocity - 7 - 4 miles per hour  
Sky - cloudy  
Rainfall - nil during experiment - trace during previous  
24 hours.  
Time of day - 5:15 P.M.

c. Field Results

Concentrations were determined at various positions at  
heights of 1 ft. 8 in. and 4 ft. above the ground. Complete tables with  
diagrams are given in the original report.

Position No. See diagram in original report	Time after burst of first shell when sample was taken. Minutes Seconds	Height above floor of trench at which sample was taken. Pt.      Inches	CONCENTRATION	
			Mg./per liter	Volume of air contained 1. volume of phosgene both at N.T.P.
5				
1	2    45	4    0	nil	nil
6	"    "	"    "	0.49	9240
12	"    "	"    "	0.23	19700
17	"    "	"    "	0.74	6120
18	"    "	1    8	0.23	19700
23	"    "	4    0	2.94	1540
26	"    "	1    8	2.69	1680
28	"    "	4    0	0.15	30200
29	"    "	1    8	0.08	56600
34	"    "	4    0	0.03	56600
39	"    "	"    "	nil	nil
4	6    45	1    8	0.71	6380
5	"    "	4    0	0.87	5200
13	"    "	"    "	0.54	8380
11	"    "	1    8	0.75	6040
15	"    "	4    0	0.15	34800
21	"    "	"    "	0.20	22600
27	"    "	"    "	0.08	56600
33	"    "	"    "	trace	trace
35	"    "	1    8	0.12	37700
38	"    "	4    0	0.12	37700
39	"    "	1    8	nil	nil
42	"    "	4    0	trace	trace
3	10    15	1    3	0.20	22600
5	"    "	4    0	0.41	11000
8	"    "	"    "	3.25	1390
14	"    "	1    9	0.25	17400
15	"    "	4    0	0.32	14200
29	"    "	"    "	nil	nil
26	"    "	4    0	0.12	37700
30	"    "	"    "	trace	trace
34	"    "	1    8	0.03	56600
37	"    "	4    0	nil	nil
41	"    "	"    "	trace	trace
41	"    "	1    8	0.08	56600
2	"    "	4    0	0.16	28300
7	"    "	"    "	0.20	22600
9	"    "	1    8	7.53	697
13	"    "	4    0	7.04	643
18	"    "	"    "	trace	trace
19	"    "	1    8	0.12	37700
22	"    "	4    0	0.12	37700
24	"    "	"    "	0.30	15100

Position No. See diagram in original report	Time after burst of first shell when sample was taken		Height above floor of trench at which sample was taken		CONCENTRATIONS		
	Min.	Sec.	Ft.	Inches	Mg./liter	Volume of air containing 1 Volume of phos- gene both at N.T.P.	
31	11	20	4	0	0.35	12900	
32	"	"	1	8	0.09	50300	
33	"	"	4	0	trace	trace	
40	"	"	"	"	0.20	22600	
43	"	"	(Dugouts ).		2.85	1600	
44	"	"	( at )		0.08	56600	
45	"	"	(lft. & in.)		nil	nil	

d. Toxicological Results:

(See report for diagram of arrangement of animals.)

Animals	NUMBER USED			Number killed	Remarks
	In trench	In dugout	In open at 22 vds.		
Goats	9	1	0	5	Only those on ex- treme right of trench survived.
Rats	18	0	12*	19	Only those on ex- treme right of trench and on ex- treme flanks in open survived.

\*Excluding 4 rats which escaped during shoot.

e. Conclusions:

1. In the open at 48 yards from the mean point of impact, the front covered by the gun was 35 yards, i.e. from rat 23 to rat 33.

2. In the trench - at 26 yards from the mean point of impact, the front covered was at least 36 yards. In view of the fact that rat 34 was outside the northern limit of the lethal cloud, it is probable that the cloud in the trench did not extent beyond goat 18.

3. Front covered by 6" howitzer - 40 yards.

6. Kuhn, Richter, Loevenhart, Kolls, Burrell, Bruce & Smith.  
B.M. XXVII-48 - B.M. XXVIII-90 - (B.M. XXIX-75).  
Smoke Screens.

Time - September 12, 1918, 2:35 P.M.

a. Object: To determine efficiency by field tests of  
centrifugal nozzle or mobile gas unit, in spraying phosgene.

b. Meteorological Conditions:

Cloudy with intermittent sunshine  
Wind - 6 miles per hour  
Air temperature - 63° F.  
Ground " - 67° F.  
Atmospheric pres. - 29.9 in.  
Relative humidity - 45%

c. Methods:

Discharge of Gas:

Amount discharged from cylinder I : 50 lbs.  
" " " II : 50 "  
Time of discharge of " I : 2 minutes (slow  
" " " " II : 28 seconds (full  
Pressure at nozzle - 200 - 250 lbs. rate)

Arrangement of Animals (Exposure 50 min.)

1. First row - 40 ft. from cylinder - 5 dogs, 20 ft. intervals
2. Second " - 100 " " - 7 dogs, 20 ft. intervals
3. Third " - 200 " " - 6 dogs, 50 ft. intervals

Arrangement of Gasoline Bottles (in same rows as animals)

1. First row - 8 bottles: (a) 20 ft. right center;  
(b) center; (c) 20 ft. left center.
2. Second row - 4 bottles: (d) 40 ft. right center;  
(e) 20 ft. right center; (f) 20 ft. left center;  
(g) 40 ft. left center.
3. Third row - 4 bottles: one behind each dog (except  
two on outer edges) - right to left (H, I, J, K).

d. Field Results

Sample Concentration in mg./l. for the following time intervals					
	: 4 Sec-	: 10 Sec-	: 30 Sec-	: 1 Min-	: 2 Min-
	: onds	: onds	: onds	: min	: utes
A	0.20	11.2	0.25	Mask broke	0.00
Vaseline	Mask	Mask			
B	in stop:	broke	broke	1.58	0.50
C	cock				
D	Suction	0.00	4.57	0.57	1.88
E	0.00	0.00	0.10	0.20	Lost in lab.
F	0.00	0.00	8.51	2.51	0.00
G	Missing	0.00	0.00	3.51	0.57
H	Stopped				
I	no	0.00	0.00	0.20	0.25
J	Poor				
K	vacuum	0.00	0.00	0.25	0.00
L	Poor				
M	vacuum	0.00	0.00	2.58	0.00
N	0.00	0.00	0.00	0.00	0.00
O	Poor				
P	vacuum	0.00	0.00	0.00	Bottle broken in lab.

e. Toxicological Results

	POSITIONS		
	Left of center	Center	Right of center
First Row			
40 ft.	Recovered		Died 36 $\frac{1}{2}$ hours
20 ft.	Died 10 hrs.		Died 52 $\frac{1}{2}$ "
O "		Died 3 hrs.	

	POSITION		
	Left of Center	Center	Right of Center
<u>Second Row</u>			
80 ft.	Recovered		Recovered
40 "	Died 150 hrs.		Died 14 days
20 "	Died 10 days		Recovered
0 "		Died 14 hrs.	
<u>Third Row</u>			
150 ft.	Recovered		Died 15 days
100 "	Recovered		Recovered
50 "	Recovered		Died 15 days

f. Conclusions:

A lethal concentration of phosgene was obtained over an area extending 100 feet from cylinders along center line, 80 feet to left on 1st line and 40 feet to left on second line of dogs. Phosgene is equally as effective as arsine in the mobile gas unit.

7. Bercroft. O.C.P. 241. (5423)

a. Object: Experiment to determine the under surface persistency of phosgene, after liberation from artillery shell.

Time - December 24, 1917 - 2:30 P.M.

b. Method:

Artillery Details:

Shell - 50 pr. C.I. filled phosgene  
Bursting charge - C (a)

Fuse - #106

Map range 2400 yards - rounds fired 15  
Time taken for all rounds - 11 minutes  
Zero time - at burst of last shell

c. Meteorological Data:

Weather Record:

Barometer - 29.97 inches  
Thermometer - Wet bulb - 42.5° F.  
Dry bulb - 43° F.  
Ground - 41.5° F.

Wind - W.E.W.-W. velocity 7 miles per hour

Sky - Cloudy

Rainfall - Nil. during exposure - 0.02" during previous 24 hours.

d. Field Results:

Concentration of Phosgene:

Samples air in craters analyzed - no trace of phosgene.

e. Toxicological Results:

Time      Individual Observations

- |             |  |
|-------------|--|
| 3 min.      | Faint indications phosgene going towards crater - none on crater area.                                       |
| 4 min.      | Not detected on crater by prone observer - faint odor like $\text{CO}_2$ - test paper negative for phosgene. |
| 5 to 8 min. | No odor of phosgene in five craters - earth turned over - odor like $\text{CO}_2$ .                          |

f. Conclusions:

Phosgene has no under surface persistency/

c. Kuhn, Richter, Burrell, Clayton and Oglesby.  
B.M. XXX-66, P.T. VIII-4389.

Firing a Livens projectile loaded with phosgene and pumice.

a. Object: To find concentration limits and persistency of a cloud of phosgene resulting from firing a Livens projectile loaded with phosgene and pumice in a trench.

b. Method:

1. Time - October 26, 1918, 8:30 A.M.
2. Projectile - Mark I Livens - 5/4 full pumice stone 1/4" in diameter, 7,574 cc. phosgene, 10% air space by volume. 85 gms. loosely packed A.I. T.N.T. #18 detonator.
3. Animals - 3 dogs at 20 ft. intervals on each side projectile. Exposure 30 minutes.
4. Samples - 4 groups of 10 samples on each side of projectile. 20, 40, 60, 100 ft. from projectile - designated left to right A-H.

c. Meteorological Data:

Fairly clear.

Wind velocity - 0.6 miles per hour, (average for 5 min.)

Temperature Air: Inside trench	-	58° F.
" " Outside "	-	57° F.
Ground temperature: Inside "	-	57.2° F.
" " Outside "	-	57.2 F.
Relative humidity: Inside "	-	94%
" " Outside "	-	94%
Barometer	-	29.9 inches

d. Field Results

Sam.: Gas concentrations in mg. per liter for the following time intervals. Sec: 0 Sec-10 Sec-1 Min-2 Min-3 Min-5 Min-10 Min-15 Min-20 Min-										
	Ones	Tens	Hundreds	Ones	Tens	Hundreds	Ones	Tens	Hundreds	Ones
A	0.08	0.23	0	0.23	0.41	0.30	0.19	0.00	0.00	0.00
B	0.03	0.15	0	0.04	0.50	0.79	0.09	0.09	0.15	0.03
C	0.15	0.09	0	1.73	4.25	3.62	0.03	0.50	0.49	0.03
D	0.51	2.35	0	13.68	3.31	5.33	1.70	4.01	7.80	0.69
E	31.98	14.88	0	7.44	1.15	0	7.58	0.41	0.61	0.30
F	0.27	0.00	0	1.08	1.65	2.13	0.97	0.09	0.19	0.22
G	0.09	0.09	0	---	2.77	---	1.63	0.03	0.09	---
H	0.10	0.03	0	0.00	0.10	0.03	0.03	0.03	0.03	---

e. Toxicological Results

Position

150-140 feet left of center	-	Unaffected
120	"	Light casualty
100	"	Died 18 hours
80	"	" 4 "
60	"	" 7 "
40	"	" 4 "
20	"	" 30 minutes
20	right	" 2½ hours
40	"	" 2½ "
60	"	" 17 "
Remainder	"	Unaffected.

f. Conclusions

1. Projectile not well thrown out of crater - small cloud - 10 feet in air - sticking close to ground.
2. Casualties - 8 deaths over front 150 feet - same as with phosgene alone.
3. Persistency -  
20 minutes after firing - not detected by man 20 feet right and 60 feet left of crater.  
30 minutes after firing - not detected by man 5 feet right and 15 feet left of crater.  
2 hours after firing - no trace detected over crater.
4. Observations exclusive of analytical results do not show any evidence that pumice renders phosgene more persistent.

9. Kuhn, Richter, Burwell, Clayton.  
P.T. VIII - A388. B.M. XXXII-93.

a. Object: Study of persistency and lethal area of projectile filled with phosgene absorbed in pumice stone.

b. Method:

Livens projectile about 9 l. phosgene (95.8%) fired statically in bottom of trench. A No. 8 detonator and 85 gm. T.N.T. loosely packed, were used in the detonator.

of Livens.

Animals - 8 dogs, 20 feet intervals each side

Exposure - 30 minutes.

Time of Firing - November 8, 1918, 8:00 A.M.

c. Meteorological Data:

Weather - clear

Temperature of air - 42° F.

Relative Humidity - 96%

Barometric reading - 29.84 inches

Wind velocity - less than 1 mile per hour

d. Field Results:

Eight samples were taken at 20 ft. intervals A-H, left to right.

Sam-Gas Concentrations in Mc. per liter for the following time intervals.											
	5 Sec	10 Sec	30 Sec	1 Min	2 Min	3 Min	5 Min	10 Min	15 Min	20 Min	30 Min
	conds	conds	conds	utes	utes	utes	utes	utes	utes	utes	utes
A	0.0	0.12	13.9	11.5	5.9	2.6	0.64	0.38	0.06	0.10	0.00
B	5.1	24.9	0.0	--	16.5	7.75	3.38	0.52	0.86	0.23	0.31
C	23.2	6.16	8.00	1.44	17.0	12.3	6.3	7.0	1.1	0.25	0.11
D	37.0	7.26	--	--	44.2	34.8	14.4	6.63	8.55	26.8	0.17
E	2.68	--	2.70	6.7	24.4	46.4	66.5	30.0	86.0	158.0	0.17
F	0.23	--	--	--	6.7	5.0	21.4	0.82	0.46	0.78	0.11
G	0.11	--	--	--	2.28	1.55	0.55	0.68	0.05	0.06	0.05
H	0.10	--	--	--	2.82	0.58	0.05	0.00	0.11	0.00	0.05

After 6 min. Cloud moved back over trench.  
 10 " Cloud very thin and just perceptible to sight.  
 15 " Cloud outside dispersed but heavy mist remained in trench 80 ft. on either side of projectile.  
 20 " Strong odor of phosgene 200 ft. N.E. of projectile. 150 ft. N.E. of projectile unbearable without masks.  
 30 " Bearable without masks on right (south) up to the projectile. On left masks were required at 50 ft.  
 1 Hour No phosgene detectable in or out of trench.

f. Toxicological Results:

<u>Position</u>			<u>Light casualty</u>
160 feet right			" "
140 "	"	"	" "
120 "	"	"	Severe "
100 "	"	"	Died 12 hours
80 "	"	"	" 38 "
60 "	"	"	" 24 "
40 "	"	"	" 2 "
20 "	"	"	" during exposure
20 "	left	"	" " "
40 "	"	"	" 2½ hours
60 "	"	"	" during exposure
80 "	"	"	" 7 hours
100 "	"	"	" 6 "
120 "	"	"	" 7 "
140 "	"	"	Severe casualty
160 "	"	"	" "

Lethal area - 100 feet to right of projectile, 120 feet to left.  
 Comparison with test of Oct. 26 (with pumice)  
 Temperature Oct. 26 - 58°F.

Nov. 8 - 42°F., temperature may account for better cloud and larger lethal area.

Lethal area - Oct. 26th with pumice, 160 feet

Nov. 8th without " , 220 " , wind conditions nearly identical.

f. Conclusions:

1. Cloud resulting from detonation of the Livens drum filled with phosgene, is denser and produces a larger lethal area, and is as persistent as that in which phosgene was absorbed in pumice.

10. Kuhn, Richter, Burzell, Clayton and Ogleby.  
B.M. IXV-60, P.T. VIII-4393.

Test of gas shell filled with phosgene and pumice.

a. Object. To find the concentration limits and persistency of a cloud of phosgene resulting from firing a Livens projectile loaded with phosgene and pumice in a trench.

b. Method.

Date - December 5, 1918, 9:15 A.M.

Projectile - Mark I Livens filled 3/4 full with pieces of pumice, size of grain of wheat. This required 6-7/8 lbs. or 8.5 liters pumice - to this were added phosgene 9,217 cc. (29.1 lbs.) 99.05% pure - air space - 10% by volume.

Position - Livens placed outside trench of old trench system.

Booster charge - 85 gms. loosely packed A-1. T.N.T.

Pyrometer - #8 inserted.

Cloud - Thrown 10 ft. in air; settled well.

Animals - 3 dogs, 20 feet intervals on each side of projectile. (Total 16 dogs).

Samples - 4 groups on each side, 30, 40, 60, 100 foot intervals, left and successive to right over period of 20 minutes.

c. Meteorological Data.

Weather - cloudy - cleared up 10 minutes after shock.

Wind velocity - 3 to 4 miles per hour.

Temperature of air - inside trench - 37° F.

" " " outside " - 37° F.

Relative humidity - inside " - 65%

" " - outside " - 65%

Barometer - 29.8 inches

a. Field Results:

Gas concentrations in ppm per liter for the following time intervals.										
Time	5 Sec	10 Sec	30 Sec	1 Min	2 Min	5 Min	10 min	15 Min	20 Min	30 Min
A	.00	5.10	4.20	2.00	.87	.00	.46	.00	.00	.00
B	9.88	13.10	5.70	1.00	1.80	.87	1.06	.40	.00	.62
C	7.35	14.00	5.70	2.01	4.40	1.30	1.72	.23	.06	.06
D	.07	4.50	---	14.20	7.95	2.02	1.90	.28	1.40	.06
E	3.90	4.30	6.36	---	---	.00	.00	---	.00	.00
F	.00	.00	.06	1.10	.96	.00	.00	.00	.00	.00
G	.00	.00	.06	.00	.00	.00	.00	.00	.00	.00
H	.00	.00	---	.06	.00	.00	.00	.00	.00	.00

b. Toxicological Results:

7 dogs killed over front of 140 feet.

c. Conclusions:

1. Cloud 10 feet in air.

2. Wind shifted to favor left side of set up.

3. Casualties:

Killed - 7 dogs - 140 foot front, 40 feet left, 100 feet left of projectile.

Severe casualties - 8

Light " - 2

4. Apparently pumice does not increase persistency, but causes cloud to spread more smoothly and with less waste of the filled actually used.

5. Persistency:

5 minutes after shot - heavy mist 20 feet right, 40 feet left of projectile.

15 minutes after firing - not detected to 10 feet right, 50 feet left.

20 minutes after firing - not detected to 5 feet right of crater, 60 feet left of crater.

30 minutes after firing - slight odor immediately over crater.

45 minutes after firing - practically no odor.

Pumice prevents booster charge from scattering

the cloud so high into air.

11. Richter, Burrell, Clayton.  
B.M. XXI-78.

This report contains a resume and comparison of data given in B.M. XXXp66 and B.M. XXXII-93.

Conclusions:

1. Phosgene absorbed in pumice does not appear more persistent than phosgene alone.
2. Lower initial and average concentration obtained with phosgene plus pumice and a toxic cloud of less extent secured.

12. G.C.P. 178. (6526)

Report on firing trials of 5" (26 cwt.) Howitzer cast iron shell charged phosgene Jan. 13, 1918.

aim Object: To determine that 15, 6" howitzer shell should fall 50 yds. upwind of every 40 yds. of front of target in order to produce satisfactory lethal effects. One trial 2/3 yds. used, other 1/3 of number of shells laid down in official pamphlet.

b. Method. Artillery Details.

No. of trial	26	27	28	29	
No. of 6" How. used	2	2	6	6	
Map range (yards)	4000	4000	4050	4000	6
Front engaged "	40	40	50	40	4050
Effective area	40x50	40x50	50x50	40x50	40
Rounds fired (ranges not included)	11	20	38	47	24
Rate of fire (B.F.)	15 sec.	15 sec.	5 sec.	3 sec.	3 sec.
Time to fire all rounds	4 min. sec.	7 min. 20 sec.	2 min. 40 sec.	3 min. 12 sec.	2 min. 5 sec.
Direction of fire	enfilade	enfilade	frontal	frontal	enfilade
Accuracy of shooting	good	good	good	good	excellent
Diagrams of arrangement of animals, trenches and fall of shells are given in report.					

c. Meteorological Data

No. of trial	26	27	28	29	30
Date	June 19, 1918	June 19, 1918	Oct. 1, 1918	Oct. 13, 1918	Oct. 16, 1918
Time of day	8:40 P.M.	9:30 P.M.	5:45 P.M.	4:40 P.M.	5:00 P.M.
Barometer (inches)	29.50	29.50	29.90	29.78	29.47
Thermometer (dry) °F	59.	57.	44.	47.	48.
(wet) °F	55.	54.	42.	44.	45.
Ground °F	55.	54.	54.	48	44.
Wind direction	NW-N, NW	NW-W, NW	W(steady)	W-W, SW	W, NW-N
Wind velocity (m.p.h)	3	4	5	4	5
Rainfall, during experiment	nil	nil	nil	nil	nil
Rainfall during previous 24 hours	0.18"	0.18"	nil	trace	trace
Sky	overcast	overcast	blue- cloudy	blue	overcast
General conditions	dull	dull	fine	fine	dull and threaten- ing, no sunshine.

d. Field Results

Psn. Section diagram	Time after explosion of first shell	Trial No. 26		Concentrations			
		Miy.	Sec.	Height above floor or trench	kg./liter Phosgene	Volume of air con- taining 1 vol. phos- gene both at N.T.P.	Liquid fill- ing phosgene in ccm. per cubic meter of sample.
25	zero			4 0	6.89	700	4.811
26	"			4 0	5.27	900	3.681
26	"			1 8	6.79	700	4.742
1	2	0		4 0	trace	trace	-----
6	2	0		4 0	trace	trace	-----
9	2	0		1 8	6.24	700	4.358
12	2	0		4 0	1.02	4400	0.712
15	2	0		4 0	0.12	40000	0.084

Post Section diagram	Time after explosion of first shell	Height above floor of trench	Mg./liter Phosgene	Concentrations			
				Volume of air con- taining 1 vol. pho- gene both at N.T.P.		Liquid fill- ing phosgene in ccs. per cubic meter of sample	
				Min.	Sec.	ft. in.	
18	"	0	4.0	1.75		2600	1.222
21	"	"	29.71			170	18.65
23	"	"	0.59			6000	0.412
3	"	30	0.06			60000	0.056
5	"	"	nil			---	---
7	"	"	trace			trace	---
12	"	"	0.65			7000	0.454
14	"	"	0.78			6000	0.345
24	"	"	11.65			500	2.187
2	4	0	trace			trace	---
6	4	0	"			"	---
8	4	0	"			"	---
11	4	0	0.80			6000	0.559
14	4	0	0.68			7000	0.475
17	4	0	0.91			5000	0.535
20	4	0	0.87			12000	0.253
2	4	30	0.09			50000	0.063
4	4	0	0.09			50000	0.063
10	4	0	trace			trace	---
13	4	0	0.31			15000	0.217
15	4	0	0.08			60000	0.056
16	4	0	0.19			25000	0.133
19	4	0	0.17			25000	0.119
22	4	0	0.76			6000	0.531
24	4	0	0.54			500	5.965
2700	"	1	trace			trace	---
2800	"	1	nil			nil	---
2900	"	1	"			"	---

Trial 25 To ascertain travel of phosgene cloud

Distance from	Mg./liter Phosgene	Volume of air containing 1 vol. phosgene both at N.T.P.	Remarks
500 yards	0.04 0.04	10000 "	Without AgNO <sub>3</sub> guard tube With " " "
500 yards	0.04 0.04	10000 "	Without " " " With " " "
1000 yards	nil nil	trace "	Without " " " With " " "
1000 yards	nil nil	trace "	Without " " " With " " "

## (2) Trial 427

Posn. No.	Time after explosion	Height above floor of trench	Mg./liter Phosgene	Concentration Phosgene		
				Volume of air containing 1 vol phosgene both at N.T.P.	Liquid fill- ing phosgene in cc. per cubic meter of sample	
	Min. Sec.	Feet In.				
1	1	40	4	0	1.55	5400
5	"	"	1	8	0.65	7000
7	"	"	4	0	0.75	6000
11	"	"	1	8	1.24	5700
13	"	"	4	0	0.52	9000
16	"	"	4	0	0.32	14000
19	"	"	4	0	0.76	6000
24	"	"	4	0	0.61	7000
27	"	"	1	8	trace	trace
3	"	50	4	0	nil	nil
6	"	"	4	0	1.01	4500
8	"	"	4	0	nil	0.705
10	"	"	4	0	nil	—
13	"	"	1	8	nil	—
15	"	"	4	0	trace	—
21	"	"	4	0	"	—
22	"	"	4	0	0.19	25000
27	"	"	4	0	0.49	9000
2	"	0	1	4	0.14	5000
8	"	"	1	4	2.02	2200
9	"	"	1	4	0.57	8000
12	"	"	1	4	1.05	4500
15	"	"	1	4	0.36	15000
18	"	"	1	4	trace	trace
21	"	"	1	4	0.16	55000
23	"	"	1	4	0.13	35000
25	"	"	1	4	0.18	25000
4	"	20	1	4	trace	trace
11	"	"	1	4	0.09	50000
14	"	"	1	4	nil	nil
17	"	"	1	4	0.14	30000
20	"	"	1	4	0.18	25000
23	"	"	1	4	trace	trace
25	"	"	1	4	0.16	30000
58 D.O.	"	"	1	4	0.08	60000
59 D.O.	"	"	1	4	nil	nil
50 D.O.	"	"	1	4	trace	—
		"	"	"	nil	—

General Average Concentrations

Trial 26				Trial 27			
	General Average Concentrations		General Average Concentration		Shell: Time	Volume of air: Mg./l.	Shell: Time
Samples and Volume of air: Mg./l.		Shell: Time	Volume of air: Mg./l.	Shell: Time			
Sample Nos. per volume of:		Burst:	per volume of:	Burst:			
1000ccm		Shoot	1000ccm	Shoot			
1 (1-4)	90,000	0.049	nil	—	5,000	0.883	nil
2 (4-9)	4,200	1.051	nil	—	6,500	0.679	nil
3 (10-19)	8,000	0.552	nil	4 min.	15,000	0.276	nil
				:0 sec.			:7 min.
4 (20-26)	900	4.906			250,000	0.166	nil
					One of 170**-25.976 mg./l		
					not included in general		
					Average concentrations		

\*\*Since the later higher figures were subsequently maintained, they are included in the general average concentration.

Direct hit in trial 26 caused high local concentration and great mortality. When higher number, low calibre shell (4.5 inches) are replaced by smaller number of high calibre shell (6 inches), the variability of concentration is greatly increased.

(3) Trial #57

Posn. No. en Diagram	Time after explosion of first shell Min.	Concentrations Phosgene		
		Mg./liter phosgene	Volume of air con- taining 1 vol. phos- gene both at M.T.P.	Liquid filling phos- gene in ccs. per cubic meter of sample.
5	1	0.26	17000	0.182
6	"	0.13	35000	0.091
11	"	0.14	30000	0.098
13	"	0.95	4800	0.663
19	"	0.09	60000	0.063
1	1-2	0.53	9000	0.370
4	1-2	0.18	25000	0.126
7	1-2	0.41	11000	0.286
9	1-2	1.40	5500	0.978
12	1-2	0.08	60000	0.056
14	1-2	nil	nil	—
16	1-2	trace	trace	—
18	1-2	0.13	35000	0.091
2	5	0.12	40000	0.084
5	"	0.39	12000	0.272
8	"	0.14	30000	0.098
10	"	trace	trace	—
15	"	0.22	20000	0.154
17	"	0.09	50000	0.063

\* Time only approximate.

## (4) Trial 682

Position No. see diagram in origi- nal report	Time after explosion	Height above shell trench	Ms./Liter Phosgene	Volumes of air containing 1 vol phosgene both at N.T.P.	Liquid filling in cc. per cubic meter of sample.
	Min. Sec.	Ft. In.			
3	1	55*	4. 0	19.53	230
12	"	55	" "	0.96	4700
14	"	"	1 8	0.46	9800
17	"	"	4.0 0	0.77	6000
22	"	"	1 8	0.98	4500
23	"	"	4 0	0.47	10000
2	2	45*	1 8	125.10	35
5	2	45*	4 0	12.74	560
8	2	45*	" "	5.05	700
11	2	45	1 8	0.47	7600
14	2	45	4 0	0.52	8700
16	2	45	4 0	2.36	1900
19	2	45	4 0	14.43	610
21	2	45	4 0	10.80	420
24	2	45	4 " "	1.27	3500
1	6	0*	" "	23.14	200
10	"	" "	" "	0.09	50000
13	"	" "	" "	0.12	40000
15	"	" "	" "	trace	trace
18	"	" "	" "	0.09	40000
20	"	" "	1 8	0.30	15000
23	"	" "	4 0	1.96	2300
27	"	" "	1 8	0.30	25000
Do 29	"	0	1 8	0.32	14000
DO 30	"	"	" "	1.19	3800
4	Unknown	"	1 8	5.50	700
6	"	"	4 0	22.72	200
7	"	"	" "	47.19	96
9	"	"	" "	5.63	800
25	"	"	1 8	0.49	9200

\*These times are uncertain, owing to shell bursts in the trench in this neighborhood.

Table to show influence of direct hits on the concentration.							
Section of trench (Nos. of sample)	Times at which samples were opened				Remarks		
	1 Min. 15 Sec.	2 Min. 45 Sec.	15 Min. 40 Sec.	Unknown			
					opened by shell splinters		
Position in brackets)					trench and shock	3 direct hits.	
	X : H <sub>2</sub> /l.	* : MG <sub>2</sub> /l.	* : H <sub>2</sub> /l.	* : MG <sub>2</sub> /l.			
1 (1-7)	: 230 : 19.2 : 56 : 122.66 : 200 : 22.08 : 700 : 6.2						
	1350 : 1.8226						
2 (8-12)	: 4700 : 0.95 : 700 : 16.308 : 500000 : 0.0883 : 600 : 5.52						
	1 : 19600 : 0.46						
3 (13-1)	: 9800 : 0.456 : 18700 : 0.5076 : 400000 : 0.1104 :						
	16000 : 0.736 : 1900 : 2.524 : trace :					at hat closeto	
	1 : 310 : 0.245					trench	
	1 : 420 : 10.514 : 15000 : 0.2944						
4 (22-28)	: 4600 : 0.96 : 3600 : 1.226 : 2300 : 1.72 : 9200 : 0.48						
	9000 : 0.6416					25000 : 0.175	

\* Volume of air per volume phosgene.

C.C.P. 178.

(5) Trial #39.						
Position No. See diagram in original report	Time after explosion of first shell	Height above ground	Mg./liter phosgene	Volume of air containing 1 volume of phosgene both at N.T.P.	Liquid filling phosgene in ccs. per cubic meter of sample	
7		16	trace	trace	—	
9		15	5.42	1300	2.389	
12		59	0.21	20000	0.147	
4		50	trace	trace	—	
6	1	7	0.21	20000	0.147	
10	1	21	0.16	30000	0.112	
1	2	20	0.09	50000	0.055	
2	"	"	0.09	50000	0.053	
3	"	"	0.09	50000	0.063	
5	"	"	trace	trace	—	
11	"	"	0.09	50000	0.063	
13	"	"	0.08	60000	0.056	
14	"	"	trace	trace	—	
15	"	"	trace	trace	—	
6	taken by ranger		0.29	16000	0.203	

e. Toxicological Data

Position (No. of trial)	CASUALTIES												PERCENTAGES						
	Dead in 48 hours			Severe, Class A and B			Light, Class C.			Dead			Severe included <i>DEAD</i>						
No. goats used	26	27	38	26	27	38	26	27	38	26	27	38	26	27	38	26	27	38	
Trench	7	7	7	2	-	4	3	-	1	2	5	2	28	0	57	71	0	81	
Dugout	1	1	2	1	-	0	-	-	1	-	1	1	100	0	0	100	0	50	
Open at 50 yards	5	4	-	0	-	-	1	-	-	3	2	-	0	0	-	20	0	-	
Open at 75 yards	4	3	-	-	-	-	-	-	-	3	2	-	0	0	-	0	0	-	
Open at 100 yards	3	3	-	-	-	-	-	-	-	1	3	-	0	0	-	0	0	-	
<i>1/27</i>																			
No. rats used	Killed			Gassed			Normal			PERCENTAGES			Killed			Killed and Gassed			
Trench	5	7	8	5	4	8	-	1	-	-	2	-	100	57	100	100	71	100	
Dugout	1	1	2	1	1	1	-	-	1	-	-	1	100	100	50	100	100	50	
Open at 50 yards	4	4	-	1	2	-	1	1	-	2	1	-	25	50	-	50	75	-	
Open at 100 yards	2	3	-	1	1	-	1	2	-	-	0	-	50	53	-	100	100	-	
No. guinea pigs used	Killed			Gassed			Normal			PERCENTAGES			Killed			Killed and Gassed			
trial No.	37	39	-	37	39	-	37	39	-	37	39	-	37	39	-	37	39	-	
On ground level	36	35	-	9	3	-	12	16	-	15	16	-	25	9	-	59	54	-	
At 4 feet	18	16	-	7	2	-	5	4	-	6	10	-	39	12	-	67	37	-	
Total	54	51	-	16	5	-	17	20	-	21	26	-	30	10	-	61	50	-	

2. Conclusions:

1. Effects of direct hit in any position where gas may be trapped, e.g., a trench, are very marked. Very high and persistent though very local concentrations of gas are produced.

2. The general average concentration of phosgene is of the order of 1/5000 to 1/10000, (0.883 to 0.4416 mg./l.) not including high local concentrations.

3. The cloud produced may be expected to travel to

50 yards in a concentration of	1/5000 to 1/10000	(0.883 - 0.4416 mg/l.)
100 " " "	" 1/30000	(0.1472 mg./l.)
500 " " "	" 1/100000	(0.04416 mg./l.)

4. The throw forward of liquid spray is about 10 yards.

5. Variations in concentrations greatly increased by replacing a large number of low calibre shell by a small number of high calibre shell.

6. The system of taking samples in the open requires considerable extension and elaboration, before reliable figures can be obtained.

13. G.O.C.P. 221 (S770).

Report on firing trials of Stokes bomb.

a. Object: To ascertain highest concentration of gas obtainable by firing 40 - 4" Stokes bombs from one mortar in 2 minutes, on 20 yard front.

b. Method:

Artillery details:

Time - November 1, 1917 - 3:30 P.M.

4" C.I. Bombs filled with phosgene.  
2

No. Stokes mortar - 1

Burating charge - Powder chambers head, instantaneous fuse (9 inch) #8 com. detonator.

Propellant charge - 1 biscuit  
Fuse #146 Mark I

Range @ 350 yards. Front engaged 20 yards.  
Effective area 20x30 yards - Rounds fired - 38  
Rounds in effective area 12 - Rate of fire - rapid  
Time taken to fire all rounds 1 min. 45 sec. -  
Direction of fire - frontal  
Ammunition - very bad.

c. Meteorological Data:

Barometer	-	29.66 inches
Thermometer, dry bulb		53.2° F.
" " "		53.0° F.
Ground temperature		52.5° F.
Wind direction		S.
Wind velocity		4-1/2 miles per hour
Sky		Overcast
Rainfall		nil during experiment 0.03 during previous 24 hours.

d. Field Results:

Observations on travel of phosgene vapors.

1300 yards from trenches - phosgene could be detected by colored test paper. (near limit of detection).

Position No. (see diagram in original report)	Time after burst of first bomb when sample was taken. Min. Sec.	Height above floor of trough at which sample was taken	Mg./liter	Volume of air containing 1 volume of phos- gene both at N.T.P.
*		ft. inches		
13				
4	35	1 8	60.61	78
8	35	4 0	16.75	270
11	"	" "	6.55	691
16	"	" "	6.25	862
18	"	" "	20.57	220
20	1	8	5.26	861
24	4	0	2.34	1940
28	1	8	0.17	26600
1		4 0	trace	—
5	5	2 0	9.45	479
9	"	" "	13.58	231
12	"	" "	12.12	374
14	"	" "	27.35	166
18	"	" "	84.55	54
21	"	" "	46.28	98
25	"	" "	32.68	139
27	"	" "	0.05	56600
1	35	2 0	0.20	22600
2	"	8	7.62	594
3	"	0	7.57	598
6	"	0	8.47	534
10	"	0	9.88	458
12	"	0	21.23	213
14	"	0	0.77	5880
17	"	0	22.82	198
22	"	0	66.94	68
28	"	0	89.43	76
5	45	Last bomb exploded	0	22600
7	"	4 0	5.49	825
10	"	" "	9.00	503
12	"	" "	15.62	290
15	"	" "	18.74	232
15	"	1 8	25.48	178
			28.80	157

Position No. (see diagram in original report)	Time after burst of first bomb when sample was taken		Height above floor or trench at which sample was taken.	Mg./liter	Volume of air containing 1 volume of phos- gene both at N.T.P.
	Min.	Sec.			
19	1	45	4 0	23.58	194
22	"	"	1 8	49.22	92
23	"	"	4 0	17.83	254
23	"	"	1 8	42.80	105
27	"	"	4 0	0.13	34800
32 (In the open)*	"	"	1 8 (above ground)	1.49	3040
8	5	0	1 8	0.19	23800
15	"	"	" "	0.08	56600
8	5	0	1 0	0.08	56600
16	"	"	" "	0.16	28300
8	2	0	" "	0.52	14200
15	"	"	" "	0.24	18400
8	2	0	" "	0.08	56500
16	"	"	" "	0.24	18900
29) In shelter	1	35	1 8	0.15	28500
31) dugouts	1	45	above floor	67.14	67
31)	15	0	of dugout	13.55	334
31)	25	0	"	4.39	1031
30) In deep dugouts.	1	45	"	5.58	811

\*The bottle in this position opened by splinters from bomb which fell near it during the ranging.

#### e. Toxicological Data

See diagram in report on arrangement of animals.

Position of goats	No. used	S A M U A L T I E S			Percentage dead	Casual- ties in- curred	Remarks
		Died in 48 hrs.	Severe Class A or B	Light Class C			
In trench	9	6	0	1	89	89	Of 7 rats, 6 died
In dugout	1	1	0	0	100	100	1 rats which died
In open, at 50 yards	5	0	2	3	0	40	Of 5 rats, 1 died
In open, at 100 yards	3	0	0	1	0	0	Of 3 rats, 1 died

2. Conclusions:

Maximum concentration 1/34 (34.55 mg./l.)

Seven greater than 1/100 (45.76 mg./l.)

Thirteen greater than 1/200 (22.89 mg./l.)

14. C.C.P. 107. (S451)

Report on firing trial of 4.5" howitzer cast iron shell - filled with phosgene.

a. Object: To determine persistency of phosgene in undergrowth - area shelled with 4.5" howitzers.

b. Method:

Artillery Details.

No. of trial - C. G. 32  
No. shells used - 4 - 4.5" howitzer  
"G" No. of shell - 0.644  
Chemical filling - phosgene  
Bursting charge - C.I.C. (a)  
Propellant # - 2nd N.G.T.  
Fuzes - 106 III  
Blank shell - 0  
Map range - 1750  
Target engaged - 60x40 yards  
Rounds fired - (ranges not included) - 50  
Rounds hit target - 34  
Rate of fire B.F. 3 Sec.  
Time to fire for all rounds 5 min. 45 sec.  
Direction of fire - frontal  
Accuracy of shooting - very good.

Two minutes after last shell exploded, 24 rats and 8 guinea pigs were placed in shelled area. Guinea pigs removed in 5 minutes, rats in 62 minutes.

c. Meteorological Data

Date July 31, 1918 - 7:45 P.M.  
Barometer - 29.75 inches  
Thermometer - dry bulb - 68°F.  
wet " - 67°F.  
Ground temperature - 63°F.  
Wind velocity - 3 miles per hour; direction S.S.E.  
S.S.W.

Sky - Cloudy  
Rainfall - nil during exposure and previous 24 hours.  
Conditions - fair

d. Results

Neither observers nor animals were able to detect the presence of phosgene.

Post mortem examination of animals showed no signs of gassing.  
It is reasonable to assume that phosgene has no persistency in undergrowth.

15. C.C.P. 205. (2862)

Experiments to determine the persistency of lethal gases in dugout - Phosgene.

Previous reports state that shell filled with phosgene exploded in open so that, cloud passes over trench containing dugout, little gas is collected in dugout.

When shell were exploded in trench, high concentrations of phosgene are found in dugout.

Description of Dugouts:

Two dugouts communicating with trench by shafts 17 feet apart; total capacity of each dugout (including shaft) 1270 cubic feet; floor 15 feet 6 inches below level of bottom of trench; floor 21 feet 6 inches below general ground level.

EXPERIMENT II. 2" T.L. Bombs filled with phosgene.

Time of trial - September 10, 1917 - 7:00 P.M.

a. Method:

Artillery Details:

3 T.L. bombs filled with phosgene, fitted with #6 commercial electrical detonators, arranged near trench as shown in sketch in original report.

Time of bursting - 5 seconds interval between #1 and 2) commencing with bomb nearest trench. Ten seconds between #2 and 3. Dugout entrances faced down wind.

b. Meteorological Data

Barometer	-	29.90 inches
Thermometer - Wet bulb	-	60° F.
Dry "	-	61.5 °F.
Ground	-	56.5 °F.
Wind Direction	-	S.E.
" Velocity	-	2½ miles per hour
Sky	-	Blue, cloudy
Rainfall	-	Nil during experiment, 0.02 inches during previous twenty-four hours.

c. Field Results:

Position (see sketch in original report)	Time after explosion of first shell	Height above floor of trench or dugout at which sample was taken	CONCENTRATIONS		
			Mg./liter	Volume air containing one volume phosgene both at N.T.P.	
	Min. Sec.	Ft. Inches			
B (dugout)	40	1	8	0.08	56600
	55	"	"	Nil	-
	1	10	"	trace	-
	1	25	"	"	-
	1	40	"	Nil	-
	1	55	"	"	-
	2	10	"	"	-
	2	25	"	"	-
C (dugout)	40	4	0	Nil	-
	55	"	"	"	-
	1	10	"	"	-
	1	25	"	"	-
	1	40	"	"	-
	1	55	"	"	-
	2	10	"	"	-
	2	25	"	"	-
A (trench)	30	1	8	18.56	244
	35	"	"	18.49	245
	40	"	"	14.10	321
	45	"	"	13.73	350
	50	"	"	12.80	353
	55	"	"	8.70	520
	1	0	"	3.24	1400
	1	5	"	4.46	1020

Little or no phosgene from bombs burst in open sinks into deep dugout, although the cloud of phosgene passing over the trench gives rise to high concentrations in trench midway between the shafts.

d. Observations on Distance Traveled by Cloud.

1550 yards distance - unpleasant odor, strong tobacco reaction lasting several hours - no lachrymation - no respirator needed.

EXPERIMENT NO. III: 2" T.M. Bombs Filled with Phosgene in  
the Trench.

Time of trial - September 11, 1917 - 6:30 P.M.

a. Method:

Artillery Details:

2 bombs on floor of trench midway between  
2 shafts of dugout. Time of exploding - 15 seconds intervals by means  
of #8 electrical detonators. Both bombs well opened, dense cloud filled  
trench. Wind blowing on to entrances of dugouts. Conditions very  
favorable to entrance into western shaft.

b. Meteorological Data:

Barometer	-	29.83 inches
Thermometer - wet bulb	-	65° F.
dry "	-	65° F.
In dugout	-	54° F.
Wind Direction	-	North
" Velocity	-	4 miles per hours
Sky	-	Dull
Rainfall	-	Nil during 1st hour - then heavy shower for several minutes - trace during previous twenty-four hours.

c. Field Results:

Samples collected in centre of dugout height -  
1 ft. 6 inches above floor.

Time after explosion of first bomb <u>Hrs.</u>	<u>Min.</u>	CONCENTRATIONS	
		Mg. per liter Phosgene	Volume of air containing one volume of phosgene both at N.T.P.
	40	77.23	59
	55	92.12	49
1	10	87.22	52
1	25	83.83	54
1	40	82.10	55
1	55	85.21	53
2	10	84.14	54
2	25	82.54	55
3	25	78.21	58
4	25	72.16	63
5	25	66.77	68
10	0	52.75	86
15	0	39.21	115
20	0	31.72	143
40	0	12.21	371
25	0	26.20	173
35	0	7.09	639
<u>Hrs.</u>	<u>Min.</u>		
1	10	3.48	1300
1	25	1.85	2450
1	55	0.73	6200
2	25	0.64	7070
2	55	0.49	9240
2	25	0.26	17400

d. Observations.

For 3 minutes 25 seconds after burst of bomb concentration in dugout remained at 1/50 to 1/50. In 15 minutes the concentration was 1/100. In one hours 10 minutes the concentration was 1/100C.

Persistency	Observations
15 Seconds	Explosion of last bomb - very dense cloud in trench.
55 "	Maximum concentration phosgene in dugout.
2 minutes	Dense cloud - light from electric torch penetrates for 1 ft.
40 minutes	Cloud in dugout still very dense - concentration phosgene 1 in 371.
55 minutes	Trench still smelt strongly of phosgene.
1 Hr. 10 min.	Still very marked smell of phosgene in trench near western shaft of dugout.

<u>Persistence</u>	<u>Observations</u>
1 hr. 25 min.	Concentration of phosgene in dugout - 1 in 8450. Electric torch penetrates across dugout. Trench practically free from phosgene except occasionally near entrance to the dugout.
2 hrs. 55 min.	Concentration of phosgene in dugout - 1 in 9340. Observer without protection could descend to within 5 steps of bottom of dugout.
3 hrs. 25 min.	Concentration of phosgene - 1 in 17400. Unprotected observer walked through dugout too much phosgene present for him to remain below.
4 hrs. 25 min.	Dugout clear of phosgene.
5 hrs. 55 min.	Only faint odor of phosgene in dugout.

EXPERIMENT NO. XXXI. 4" C.L. Stokes Bomb Filled Phosgene in Trench.

Time of trial - September 28, 1917 - 10:00 A.M.

a. Method

Artillery Details

2 Stokes bomb, 2 feet apart at bottom of trench midway between 2 shafts of dugout, exploded 30 seconds intervals. Entrance to dugouts faced directly down wind - samples collected in center of dugout 1 ft. 8 in. above floor.

b. Meteorological Data:

Barometer	-	29.99 in.
Thermometer - wet bulb	-	54.4° F.
dry "	-	55.8° F.
ground	-	60° F.
Wind direction	-	Southwest
" Velocity	-	7 miles per hour
Rainfall	-	nil during exposure, trace during previous 24 hours

c. Field Results

Time after explosion of first bomb	Hrs. Min. Sec.	CONCENTRATIONS	
		Mg. per liter Phosgene	Volume of air containing one volume phosgene both at N.T.P.
	50	17.38	261
	45	32.36	140
1	0	43.40	104

Time after explosion of first bomb			CONCENTRATIONS	
Hrs.	Mins.	Secs.	Mo. per liter Phosgene	Volume of air containing one volume phosgene both at N.T.P.
1	15		51.75	87
1	30		51.52	88
2	0		50.58	90
2	30		47.07	96
3	0		43.11	94
4	0		44.55	102
5	0		43.03	108
10	0		22.09	141
15	0		22.24	204
20	0		11.88	331
50	0		2.84	1600
1	20		0.75	6040
1	50		0.32	14200
3	0		trace	-
4	25		0.06	75500
5	47		trace	-

4. Observations:

Persistence	Observations
30 Seconds	Last bomb exploded. Pool of liquid phosgene on floor of trench.
1 Min. 30 sec.	Maximum concentration of phosgene (1 in 88) attained in dugout.
2 Min.	No liquid phosgene left on floor of trench.
9 Min.	Trench between entrances of dugout clear of phosgene.
26 Min.	Detected in trench just outside western shaft of dugout. Phosgene still issuing from western shaft. Unprotected observer to within 3 steps bottom eastern shaft - encountered strong concentration of phosgene.
1 hr. 20 min.	Phosgene still fairly strong in dugout and western stairway decreasing.
1 hr. 50 min.	Test paper slow reaction in dugout - faint odor phosgene still enough to be untenable.
3 hr.	Test paper slow reaction in dugout - faint odor phosgene still enough to be untenable.
4 hr. 25 min.	Phosgene not detected - acid fumes noticeable.
5 hr. 47 min.	Dugout and stairway clear of visible cloud.

EXPERIMENT NO. IV: 4.5" C.I. Howitzer Shell (Mark V)  
Filled Phosgene in Trench.

Time of Trial - Oct. 5, 1917 - 5:00 P.M.

a. Method

Artillery Details

Two howitzer shells - in trench midway between entrance to dugout, exploded separately, interval of 30 seconds between; wind blowing down trench across entrances to dugout.

b. Meteorological Data

Barometer	-	29.75 inches
Thermometer - wet bulb	-	44° F.
dry "	-	45° F.
ground	-	42° F.
Wind direction	-	E.E.-W.N.W.
" velocity	-	11 miles per hour
Sky	-	Cloudy
Rainfall	-	Nil during exposure - 0.24 inches during previous 24 hours.

c. Field Results

Time after explosion of first shell	Samples collected in center dugout 1 ft. 8 in. above floor.		C O N C E N T R A T I O N S
	Mg./liter	Volume of air containing one volume of phosgene both at N.T.P.	
Hr. Min. Sec.			
	30	trace	-
	45	5.51	822
1	0	12.08	375
1	15	17.20	253
1	30	16.36	277
2	0	13.86	327
2	30	13.90	326
3	0	14.48	313
4	0	13.00	348
5	0	9.86	459
10	0	2.84	1590
15	0	0.27	16800
20	0	0.08	56000
20	0	nil	-
1	20	nil	-

d. Observations

Time	Observations
30 Seconds	Explosion of last shell.
1 Min. 35 Sec.	Maximum concentration of phosgene in dugout - 1 in 263.
5 Minutes	Very strong smell of phosgene
15 Minutes	in the trench
28 Minutes	Trench and entrances of dugout clear of phosgene.
50 Minutes	Phosgene could only just be detected in dugout by smell and test paper.
1 Hr. 20 Min.	Dugout clear of phosgene - not detected by smell or test paper.

General Observations

1. High concentrations of phosgene in deep dugouts not expected from shell and bombs bursting near the trench. Bursting in trench or on top of parapet may produce high initial concentration.
2. Impossible to state time at which dugout will be clear of gas - depends on weather especially wind velocity and ventilation of dugout.
3. All dugouts used in these experiments unprotected.

16. C.C.P. 216. (5993)

Report on firing trials of 4.5" howitzer C.I. mark I shell  
filled with phosgene.

a. Method

Saturday, March 9, 1918, 5:15 P.M.

Artillery Details

Number of 4.5 howitzer used. 2

Type of shell, C.I. mark I.

Max range, 1750 yards.

Front engaged, 40 yards.

Effective area 40x30 yards.

Rounds fired, 51.

In effective area, 42

Rate of fire, battery fire, 3 seconds with pause.

Time taken to fire all rounds, 6 minutes 10 seconds.

b. Meteorological Data

Barometer - 29.85 inches

Thermometer - dry bulb 45° F.

wet " 40° F.

ground. 38° F.

Wind direction - South East.

Wind velocity - 3 to 1 miles per hour.

Sky - blue

Rainfall - nil during exposure, or previous 24 hours.

c. Field Results

Position (see ori- ginal)	Time after explosion or first shell	Height above floor, trench	Mg./L	Concentrations	
				1 Part in	Liquid per cubic meter in ccs.
Min. Sec.		ft. in			
1	0	45	4 0	0.12	40000
1	"	"	1 8	0.52	9000
1	"	"	4 0	1.07	4200
6	"	"	" "	1.04	4400
9	"	"	" "	nil	-
14	"	"	1 2	0.08	60000
17	"	"	4 0	0.16	30000
18	"	"	1 8	nil	-
23	"	"	4 0	0.08	60000
24	"	"	" "	0.19	25000
5	1	20	1 8	nil	-
6	"	"	" "	0.55	8000
8	"	"	4 0	1.14	4000
13	"	"	1 63	0.46	11000
15	"	"	4 0	0.71	6000
17	"	"	" "	1.90	2400
19	"	"	" "	1.91	2400
22	"	"	" "	0.08	60000
2	2	50	" "	0.42	11000
11	"	"	" "	0.39	12000
12	"	"	1 8	0.16	50000
16	"	"	4 0	11.27	400
21	"	"	" "	0.08	60000
3	4	35	1 8	0.08	60000
4	"	"	4 0	0.18	25000
7	"	"	" "	0.18	250000
10	"	"	1 8	0.09	50000
10	"	"	4 0	1.97	2300
15	"	"	" "	trace	-
19	"	"	1 8	1.15	44000
19	"	"	" "	trace	-
Shelter dugout	"	"	above floors	trace	-
Deep dug out, 25	"	"	of the dugout	trace	-
20 Open- ed by shell at	2	0	1 8	27.51	160
					19.220

Inasmuch as goat No. 1 was killed by a plinter and that very high local concentrations of phosgene was recorded at sampling positions 20 and 21, it seems probable that an unobserver shell must have been in this position of the trench towards middle of period during which samples were taken (4 minutes 36 seconds, the trial lasted 6 minutes 10 seconds).

Concentrations in mg./l. of phosgene.

Trench : Sampling : Time after commencement of firing

Sector	Position	45 Seconds	1 Min. 30 Sec.	12 Min. 29 Sec.	14 Min. 30 Sec.
1	1 - 4	0.1104		0.0736	0.0736
		0.4907			0.0736
		1.0514	0.1766	0.4014	0.1766
2	5 - 11	1.0036	nil		0.1766
			0.552		0.0883
		nil	1.104	0.368	0.192
3	12 - 18	0.0736	0.4014	0.1472	
		0.1472	0.735		
4	19 - 22		1.84		trace 0.11.04*
			1.84		1.104 127.60*
5	23 - 24	nil			
		0.0736			

\*Local high concentrations probably due to burst of shell in trench.

These figures are not indicated in table-

Trench Sector	Average concentration for total period	Average concentration for whole trench, durin total period
1	0.1766	
2	0.4014	
3	0.552	0.6793
4	1.5771	

Accurate prediction of deaths and severe casualties possible from consideration of concentrations alone, when states as above.

d. Toxicological Results:

Number and arrangement of goats in trench and in open shown in diagram in original report.

Position	No. of:	Casualties		Percentage	Remarks
:	: Dead	: Severe	: slight	: died	: Severe :
:	: 48 hours	: Class	: class	:	: Class inc
:	:	: A or B	:	:	: cluding :
:	:	:	:	:	: died :
Trench	8	1	3	2	14 57
In open	:	:	:	:	:
at 50 yds	5	0	1	2	0 20
75 yards	4	0	0	3	0 0
100 "	3	0	0	3	0 0

One goat was killed by a splinter.

Observation on travel of phosgene -

Cloud travel North West - odor persisted 1200 yards from trenches, limit of detection by odor or test paper 200 yards.

e. Comparison

This trial (phosgene 9) with phosgene experiment 2.

	Phosgene 2	Phosgene 9
Wind velocity, miles per hour	1 - 3	5 - 1
Temperature - Wet bulb °F.	56.5	40.
Dry " "	58.	43.
Ground "	50.	38.
Accuracy of shooting	very good	excellent
Percentage deaths	89	14
Percentage deaths and severe casual- ties	100	57
Average concentration of phosgene	2.945 mg./l.	0.679 mg./l.
Bursting charge	21 gram tetryl 2 oz. smoke pellet	

Failure of trial due to use of smoke pellet for opening the shell.

(C. I. P. 126. (4708)

(2) / Report on firing trial of 4.5" Howitzer C. L. Mark I shell filled phosgene (G 536).

a. Method:

Artillery Data:

Time of trial - May 18, 1918 - 3:30 P.M.

Map range, yards - 1750

Front engaged, yards - 40

Effective area, yards - 40x50

Rounds fired - 50

Round in effective area - 50

Rate of fire, B.F. - 5 sec.

Time to fire all rounds - 6 minutes 15 seconds

Firing trial conducted in bright sunshine and ground temperature higher than air, conditions usually considered unfavorable due to upward dissipation of the gas.

b. Meteorological Data

Barometer - 29.90 inches  
 Temperature, dry bulb - 71. °F.  
 wet " - 60. °F.  
 ground - 76. °F.  
 Wind direction - NNE  
 " Velocity - 3 - 7, mean 5 miles per hour  
 Sky - blue  
 Rainfall, during experiment - nil  
 previous 24 hours - nil  
 Weather - fine, bright sunshine

c. Field Results

Position (see ori- ginal)	Time after explosion of 1st shell:	Height above trench Min.	Concentrations		Liquid phosgene in ccs. per cubic meter.
			Sec.	Ft. : In.	
				Mg./ liter	1 part in
1	: 1	: 5	: 4	: 0	8.90
3	:	:	:	:	500
6	:	:	:	:	150
8	:	:	: 1	: 8	11.74
10	:	:	: 4	: 0	nil
12	:	:	:	:	—
15	:	:	:	:	390
18	:	:	:	:	—
20	:	:	:	:	—
23	:	:	:	:	—
25	:	:	:	:	—
26	:	:	:	:	—
1	:	: 55	: 1	: 8	—
3	:	:	:	:	—
5	:	:	:	:	—
8	:	:	:	:	—
10	:	:	:	:	—
12	:	:	:	:	—
14	:	:	:	:	—
16	:	:	:	:	—
18	:	:	:	:	—
23	:	:	:	:	—
25	:	:	:	:	—
27	:	:	:	:	—
21	:	:	:	:	—

Position : Time after explosion			Height above ground	Concentrations (mg./l.)	1 part in	Liquid phosgene in ees. per cubic meter
Min.	Sec.	Ft.	In.			
2	3	12	4	0	nil	---
4	"	"	"	16.01	280	11.21
7	"	"	"	3.12	1500	2.179
9	"	"	"	trace	---	---
11	"	"	"	nil	---	---
14	"	"	"	0.19	25000	0.153
17	"	"	"	0.87	5000	0.608
19	"	"	"	0.50	9000	0.346
21	"	"	"	0.45	10000	0.314
22	"	"	"	0.09	50000	0.063
24	"	"	"	0.08	60000	0.056
30*	"	"	"	nil	---	---
2	4	8	2	trace	---	---
4	"	"	"	98.26	46	68.63
7	"	"	"	5.70	800	5.981
9	"	"	1	8	3.65	2.599
11	"	"	4	0	0.91	6.635
13	"	"	"	"	1.13	0.789
16	"	"	"	"	0.54	0.577
17	"	"	1	8	0.23	0.161
20	"	"	4	0	0.17	0.119
24	"	"	"	"	0.45	0.314
26	"	"	1	8	0.27	0.169
28**	"	"	--	--	nil	---
29**	"	"	--	--	trace	---

\* Samples positions 30 and 31 were taken 50 yards from trench, 1'8" above ground.

\*\* Samples positions 28 and 29 were taken in dugouts, 1'8" above floor.

#### General average concentrations.

Sector	Samples Nos.	G.A.C.	Concentration not included in G.A.C.	Remarks
No.	on diagram	Line	literature	
1	1 - 5	4.0145	129.44 and 96.00	The concentrations not included in the general were obtained in close proximity to and immediately after the burst of direct hits.
2	6 - 12	2.3212	-----	
3	13 - 20	0.4507	-----	
4	21 - 27	0.1766	-----	

**d. Toxicological Results**

For diagrams showing positions of animals and sampling bottles see original report.

Position	No. of goats	Casualties			Percentages		
		dead in 48 hours	Severe class	Light class	Dead	Severe class	
					including dead		
In trench	7	1	5	6	14.5		57
In dugout	1	0	1	0	0		100
In open at 50 yards	5	0	0	5	0		0
At 75 yards	2	0	0	2	0		0
At 100 "	2	0	0	2	0		0

Position	No. rats	Gassed		Normal	Dead	dead and gassed
		Dead,	48 hours			
In trench	7	7	0	0	100	100
In open at 50 yards	6	1	3	1	20	80
At 75 yards	2	1	0	1	50	50
" 100 "	2	1	0	1	50	50

Observations on travel of phosgene vapors.  
Detected by observers 500 yards down wind - traces 600 yards.

**e. Remarks**

1. General trend of the phosgene vapor was to rise from ground in its passage to and over the trench. Observers 600 yards away were not wearing masks, whereas, in recent trials phosgene caused lacrimation at 1750 yards.
2. Results better than anticipated; rats more sensitive than goats; casualties on goats due to local high concentrations or direct hits.
3. Results show that bombardment in sunshine might be successful some tests needed for conclusions.

(3) C.C.P. 216, (3991)

(3) Report on the simultaneous firing of gas and H.E. shell. 1 - 4.5" howitzer Mark I shell filling phosgene, and 18 P.D.R.Q.F. service H.E. shell.

a. Object. To see whether effects produced by gas shell are seriously impaired by simultaneous firing of H.E. shell.

b. Method. Two squares 60 by 60 yards, with caged guinea pigs at 10 yards intervals.

c. Meteorological Data.

Date of Experiment	-	5-12-18	3-20-18
Time of day	-	12:30 P.M.	6:00 P.M.
Barometer, inches		29.70	30.06
Temperature - wet bulb °F.		50	45.5
dry "		55	47
ground		59	58
Wind, direction		S-E	W
velocity, miles per hour		5-7	4-7
Rainfall, during experiment nil			nil
previous 24 hours nil			nil

d. Toxicological Results.

(See diagrams, original report).

	No. animals	Killed	Severe casualties	Gases	Normal	% killed, severe	Normal	casualties, gassed
Phosgene only	45	8	4	21	12	18	73	
Phosgene plus H.E.	44	2	12	17	13	4	70	
Phosgene only	48	12	3	16	17	25	65	
Phosgene plus H.E.	45	23	1	8	11	53	76	

e. Mark

Conditions of first experiment - not altogether favorable, ground temperature higher than air temperature, causing upward convection currents.

Conditions of second experiment - phosgene plus high explosive showed more casualties from gas than phosgene only very significant.

f. Conclusions:

1. No doubt that 18 pdr. H.E. may be used in conjunction with 4.5" howitzer shell, filled with phosgene, without diminishing the effect of the phosgene.

2. The 18 pdr. H.E. shell may be fired round for round with the 4.5" phosgene shell, and certainly in the proportion of 4 H.E. shell to 5 phosgene shell.

17. C.C.P. 42. (4328)

Experiments to determine concentration of gas produced in trenches by the explosion of 6" trench howitzers, cast iron, Mark I, bomb filled with phosgene.

a. Methods

Artillery Data

Bombs used	-	6" T.M. cast iron Mark I.
Filling	-	Phosgene (C 545)
Bursters	-	10 grams Ophorite
Ignition	-	No. 8 detonator sleeves, filled R.F.G. 2, for electric ignition.

Bombs exploded at rest:

Fragmentation	-	Well opened.
Path of cloud	-	Travelled well over the trench, and visible up to 300 yards down wind.

b. Meteorological Data

Temperature of the air:

Dry bulb	-	47° F.
Wet "	-	44.5° F.
Temperature of ground:		53° F.
Wind velocity:		6 miles per hour
Direction of winds:		E.-N.E.
Sky:		Blue - cloudy
Rainfall:		Nil during experiment - trace during previous 24 hours.
Weather:		Fine
Barometric Pressure:		29.6 inches
Time of day:		11:50 A.M.

c. Field Results

On platform (1 foot 8 inches above ground level).

Sear- ple	Position No.	Time after explosion	CONCENTRATIONS	
			g./liter	Volume of air containing one volume phosgene both at H.T.P.
1	1	4 Sec.	2.11	2100
2	2	4 "	4.07	1100
3	3	4 "	2.58	1800
4	4	4 "	10.09	450

## In trench

Sam- ple No.	Position No.	Time after explosion of bombs at which samples were taken	Height above floor of trench at which sam- ples were taken	CONCENTRATIONS		Volume of air con- taining one volume of phosgene.
				Min.	Sec.	
				Feet	Inches	
5	1	0	10	4	6	23.32
6	1	0	15	3	5	16.71
7	1	0	20	2	6	19.72
8	1	0	30	1	6	3.24
9	1	0	45	1	8	1.24
10	1	1	0	1	8	0.82
11	1	1	15	1	9	0.36
12	1	1	30	1	9	0.12
13	2	0	10	4	6	11.19
14	2	0	15	3	6	18.66
15	2	0	20	2	6	8.38
16	2	0	30	1	6	1.35
17	2	0	45	1	8	0.72
18	2	1	0	1	8	0.45
19	2	1	15	1	8	0.45
20	2	2	0	1	8	0.08
21	3	0	10	4	6	10.27
22	3	0	15	3	5	21.73
23	3	0	20	2	6	6.58
24	3	0	30	1	6	1.07
25	3	0	45	1	8	0.16
26	3	1	0	1	8	trace
27	3	1	15	1	8	nil
28	3	1	30	1	8	trace
29	4	0	10	4	6	19.89
30	4	0	15	3	6	19.15
31	4	0	20	2	6	7.67
32	4	0	30	1	6	1.76
33	4	0	45	1	8	0.28
34	4	1	0	1	8	0.23
35	4	1	15	1	9	0.15
36	4	1	30	1	8	0.40
37						11000

In dugout

Sam- ple No.	Position	Time after explosion of bombs	Height above floor of trench at at which samples were taken	CONCENTRATION	
				Mg./liter	Volume of air containing one volume phosgene both at N.T.P.
		Min. Sec.	Foot Inches		
37	center	1 0	1 8	0.69	50000
38	of dug-	2 0	1 8	0.80	15000
39	out	3 0	1 4	2.01	1600
40		4 0	1 4	0.61	7000
41		5 0	1 8	0.80	6000
42		8 0	1 8	0.61	10000
43		10 0	2 8	0.58	5000
44		40 0	1 8	nil	—

d. Toxicological ResultsObservations in Dugout

A white cloud penetrated to the foot of the eastern shaft in 20 seconds after the explosion of the bombs, and to the foot of the western shaft in 50 seconds; phosgene was detected at the center of the dugout in 30 seconds in amount sufficient to necessitate wearing a respirator. Lightmatory effects of an intense nature were produced when the eyes were exposed at 3, 6 and 14 minutes after zero. At 25 minutes after zero the odor of phosgene was perceptible in the trench, and phosgene vapor in fairly strong concentrations was encountered half-way down the eastern and western shafts when the dugout was entered. At 65 minutes after zero phosgene was just detectable by smell in the dugout, but no discomfort was caused by the atmosphere.

e. Remarks

The samples on the top of the parapet (Nos. 1-4) were evidently taken before the densest part of the cloud had reached the positions.

In three minutes phosgene was present in the dugout in fairly high concentration. From that time until after 10 minutes there was a fairly high concentration of phosgene moving backwards and forwards over the sampling position in the center of the dugout.

### Experiment II.

a. Method One 6-inch T.H. cast iron Mark I bomb, filled with phosgene, (0.548), was exploded at the bottom of a trench, and samples of the atmosphere were collected.

#### b. Meteorological Data

Wind velocity	-	5 to 6 miles per hour
Wind direction	-	N.-E.-N.W.
Temperature of air:		
Dry bulb	-	50° F.
wet "	-	45° F.
Temperature of ground:	-	55° F.
Rainfall	-	Nil during experiment and previous 24 hours
Weather	- fine	
Barometric pressure	-	29.69 inches
Time of day	-	10:50 A.M.

#### c. Field Results

##### In trench

Sample No.	Position No.	Time after explosion	Height above floor of trench at which samples were taken	CONCENTRATIONS					
				Min.	Sec.	Feet	Inches	Mg./liter	Volume of air containing one volume phosgene both at N.T.P.
1	R1	0	15	1	8	10.61		430	
2	R1	0	20	4	0	13.34		250	
3	R1	0	50	1	8	11.09		410	
4	R1	0	55	4	0	3.09		1500	
5	R2	0	35	1	8	1.89		2400	
6	R2	0	40	4	0	4.96		900	
7	R2	1	10	1	8	24.44		190	
8	R2	1	15	4	0	5.41		840	
9	R3	0	20	1	8	13.75		330	
10	R3	0	20	4	0	5.05		900	
11	R3	0	45	1	8	33.22		140	
12	R3	0	45	4	0	7.52		600	
13	R3	2	0	1	8	2.70		1700	
14	R3	2	0	4	0	1.57		2900	

Sample No.	Position No.	Time after explosion	Height above floor of trench at which samples were taken			CONCENTRATIONS			
				Min.	Sec.	Foot	Inches	Mg./liter	Volume of air containing one volume phosgene both at N.T.P.
15	R4	0	35	1	8	19.87		230	
16	R4	0	35	4	0	4.99		900	
17	R4	0	55	1	8	18.81		240	
18	R4	0	55	4	0	13.27		340	
19	L1	0	15	1	8	2.21		2000	
20	L1	0	20	4	0	2.43		1900	
21	L1	0	50	1	8	49.45		92	
22	L1	0	55	4	0	22.59		200	
23	L2	0	35	1	8	1.92		2400	
24	L2	0	40	4	0	1.08		4200	
25	L2	1	10	1	8	41.80		110	
26	L2	1	15	4	0	10.75		420	
27	L3	0	20	1	8	34.72		54	
28	L3	0	20	4	0	31.79		140	
29	L3	0	45	1	8	23.18		200	
30	L3	0	45	4	0	27.71		160	
31	L3	2	0	1	8	3.67		1200	
32	L3	2	0	4	0	3.28		1400	
33	L4	0	30	1	8	31.59		140	
34	L4	0	30	4	0	17.43		260	
35	L4	1	10	1	8	6.02		800	
36	L4	1	10	4	0	9.23		500	

Sample No.	Position No.	Time after explosion	Height above floor of trench at which samples were taken			CONCENTRATIONS			
				Min.	Sec.	Foot	Inches	Mg./liter	Volume of air containing one volume phosgene both at N.T.P.
39		1	0	1	8	25.72		170	
40	center	2	0	1	8	22.54		200	
41	center	3	0	1	8	20.14		220	
42	center	5	0	1	8	16.78		270	
43	dug-	10	0	1	8	8.81		500	
44	out	15	0	1	8	5.40		800	
45	so	30	0	1	8	2.92		1600	
				Mins.	Min.				
46	foot of shaft.	1	0	1	8	0.64		7000	
47	center	1	0	1	8	0.51		7000	
48	center	2	30	1	8	0.13		50000	
49	dugout	8	0	1	8	0.09		50000	
50	dugout	8	0	1	8	nil		—	

d. Field Results:

Observations:

The bomb opened well and a good volume of cloud was thrown up and out of the trench. The actual bay in which the bomb was exploded was clear of visible cloud in 75 seconds, but visible vapors were still present in two adjoining bays at 2 minutes. The bay on the eastern side was not clear of mist until 5 minutes after the explosion of the bomb.

A dense cloud of phosgene immediately penetrated down both the eastern and western shafts; it was impossible to see across the dugout owing to the opacity of the cloud. At 60 minutes after zero a cloud of considerable opacity was still present in the dugout. At 90 minutes after zero it was just becoming possible to see across the dugout, although fumes were still present in the bottom of both shafts. At 120 minutes after zero phosgene vapors were detected on reaching the fourth step down each shaft of the dugout and visible fumes were still in the dugout. At 180 minutes after zero the dugout was free from phosgene, but traces of hydrochloric acid were detected.

e. Remarks:

The concentrations reported show a travel of vapor of phosgene in high concentration along the trench on both sides of the bay in which the bomb was exploded. The highest concentrations were 1/92 at position LI at 50 seconds and 1/54 at position LS at 30 seconds after zero. At one minute after zero phosgene was present in the dugout in concentrations 1/180, and at the end of 30 minutes the concentration had fallen to 1/1600. At 2 hours 1/50000 phosgene was present.

18. C.C.P. 216. (4021)

Report on Firing Trial of 4.5" Mortar G.I. Mark X  
Shell, Filled Phosgene.

a. Method

Time of trial: March 15, 1918 at 5:45 P.M.

Artillery Details

More rapid firing with higher wind velocity  
than usual.

Max range 1750 yards - Front engaged 40 yards.  
Effective area 40 x 30 yards - Rounds fired 59  
(9 ranges).

Rounds in effective area 31 - Rate of fire 3.5 P.  
2 seconds.

Time taken to fire all rounds 2 minutes 15 seconds.

b. Meteorological Data

Barometer - 29.99 inches  
Thermometer: dry bulb 47°F.  
wet " 45°F.  
ground " 45°F.  
Wind - N.E. - N.W.E. Velocity 8-6 miles per hour  
SKY - blue  
Rainfall - None during exposure nor in previous  
24 hours.

c. Fiald Results

2,600 yards from trenches southwest of battery -  
strong odor, turned test paper, longest distance ever observed to travel  
at Porton. 3,000 yards (beyond woods) - not detected.

Position (sec dia- gram in original report)	Time after burst of first shell when sample was taken	Height above floor of trench at which sample was taken	Hg./liter	Volume of air contain- ing volume of phosgene both at NTP		Volume of liquid fill- ing in ccs. per cubic meter
				Sec.	Ft.	
5	15	4	0	5.01	900	3.498
10	"	"	"	0.11	40000	0.077
10	"	1	8	trace	-	-
15	"	4	0	nil	-	nil
19	"	1	8	nil	-	nil

Position (see dia- gram in original report)	Time after burst of first shell when sample was taken	Height above floor	Mg./liter	Volume of air containing 1 volume of phos-		Volume of liquid filling trench at which sample was taken in ccs. per cubic meter. M.T.P.
				Min.	Sec.	
				Ft.	In.	
19		15	4	0	trace	-
25	"	"	4	0	0.52	8700
27	"	"	2	8	2.83	1600
29	"	"	1	8	1.05	4400
4	45	4	0	0.68	7000	0.475
8	"	1	8	0.12	40000	0.084
9	"	4	0	0.08	60000	0.056
14	"	"	2	8	0.30	15000
16	"	"	1	8	0.64	7000
18	"	"	4	0	2.65	1700
23	"	"	"	"	2.26	2000
27	"	"	1	8	28.52	159
28	"	"	4	0	0.57	7000
2	"	"	4	0	1.22	5700
7	"	"	"	"	0.46	10000
13	"	"	"	"	0.20	26000
14	"	"	"	"	0.92	4900
17	"	"	4	0	0.78	6000
22	"	"	"	"	0.17	25000
1	1	50	"	"	trace	-
6	"	"	"	"	0.51	9000
11	"	"	"	"	0.35	15000
12	"	"	1	8	0.25	17000
15	"	"	4	0	0.17	26000
20	"	"	"	"	0.55	8000
21	"	"	1	8	0.95	4800
24	"	"	4	0	1.53	3000
29	"	"	"	"	0.12	40000
50	shelter dugout	"	"	"	0.12	40000
21	deep dugout	"	above floor		0.08	60000
32	shelter dugout	"	of dugout		nil	-
3	Unknown	1	8		0.78	6000
6	"	"	"		1.19	2800
24	"	"	"		1.29	3500
26	"	4	0		11.74	386

d. Toxicological Results

Fall of shell and arrangement of animals in diagrams,  
see original report.

Position	No. of goats used	Casualties			Percentage		Remarks
		Dead in 48 hrs.	Severe Class A or B	Light Class C	Dead	Severe casual- ties in cluding dead	
In trench	7	0	2	5	0	29	of 7 rats 0 died
In dugout	1	0	0	0	0	0	1 rat which survived
In open at 50 yards	5	0	0	5	0	0	of 5 rats 0 died
In open at 75 yards	4	1	1	1	25	50	of 4 rats 0 died
In open at 100 yards	3	0	0	1	0	0	of 3 rats 0 died

19. C.G.P. 216. (2485)

Report on firing trial of 4.5" howitzer cast iron  
shell filled with phosgene.

a. Method

Time of trial - September 24, 1917- 5:40 P.M.

Artillery Details:

No. of experiment - 2

Map Range 1750 yards - front engaged 2D yards.

Effective area 50x50 yards - rounds fired 36  
Rounds in effective area 21.

" " " " from range table 25.

Rate of fire - B.F. 5 seconds

Time taken to fire all rounds - 4 minutes 3D seconds

Direction of fire - frontal

Accuracy of fire - very good

No. howitzer used - 2

Type of shell - C.I. with long narrow exploder tube

Bursting charge - 21 grams trotyl

Propellant lst. chg. - ballistite

Fuse - 44 Mark III x A

Blind shell - 2 & 3 ricochet

b. Meteorological Data:

Barometer - 29.98 inches

Thermometer - wet bulb - 56.5° F.

dry " - 58° F.

ground - 50° F.

Wind direction - Between South West and South, South  
West.

" velocity - 1-8 miles per hour

Sky - blue

Rainfall - nil during exposure and previous 24 hours

c. Field Results:

Position number see ori- ginal report	Time after burst of first shell when sample was taken	Height above floor of trench at which sample was taken	C O N C E N T R A T I O N		
				Mg./liter	Volume of air containing one volume phosgene both at N.T.P.
		Min. Sec.	Feet Inches		
4	2	0	4 0	4.45	1020
8	"	"	" "	20.18	224
9	"	"	1 8	28.98	156
10	"	"	4 0	0.48	9450
12	"	"	1 8	7.54	600
14	"	"	4 0	5.02	902
2	4	0	4 " "	1.24	2650
5	"	"	" "	6.02	758
12	"	"	1 8	2.66	1700
15	"	"	4 0	8.09	1470
16	"	"	1 8	1.14	2970
1	4	20	"	0.59	6560
1	"	"	1 8	0.49	9240
3	"	"	4 0	0.68	6660
4	"	"	1 8	0.84	7070
5	"	"	" "	1.97	2300
6	"	"	4 0	1.92	2360
7	"	"	" "	8.27	548
11	"	"	" "	1.56	2900
13	"	"	" "	7.73	586
15	"	"	" "	3.51	1370
17	"	"	" "	0.86	12600
17	"	"	1 8	0.41	11000

Bottles at 8 and 9 showing 1/224 and 1/156 were opened soon after shell burst close by.

d. Toxicological Results:

Animal used	No.	Dead 48 hours	Casualties			Percentage Dead	Casualties in- cluding dead
			Severe A or B	Class B	Slight Class C		
<u>In trench</u>							
Goat	9	8	1 (A)	-	-	89	100
Rat	9	9	-	-	-	100	100

Codes:

- (a) Severe casualty (A) probably die 3-4 days after bombardment.
- (b) Severe casualty (B) out of action for considerable period.
- (c) Light casualty (C) out of action for short period.

Of the 26 dead animals, twenty-two died within 14 hours after the trial. Of the 2 goats as casualties (A) would probably have died in another 24-48 hours. Since 75% of goats and 100% of rats exposed in open, 50 yards beyond the line of trench were killed, it follows that the lethal travel of cloud of phosgene liberated from 4.5" Q.L. shell must be at least 50 yards and probably over 100 yards.

20. "C.P. 216. (3670)

Report on firing trial of 4.5" C.I. Mark I  
howitzer filled phosgene.

a. Object: To test lethal qualities of phosgene.

b. Method:

Time: January 4, 1918 - 3:30 P.M.

Artillery Data:

No. of experiment - 6

Number of rounds fired - 58 Map range, 1750 yards  
Front engaged, 40 yards Effective area, 40x30 yards

No. of rounds in effective area, 36

Rate of fire B.M., 5 seconds Total firing 9 minutes

No. of rounds in effective area from range table, 34

No. howitzer used, 2

Type - C.I. Mk. I

"Q" number - Q 476

Bursting chg. C - 1G (a)

Propellant chg. - 2d Ballistite

Fuse - #106

Blind shell - 0

c. Meteorological Data:

Barometer - 30.14 inches

Temperature: wet bulb - 31.5°F.

dry " - 32.5°F.

ground - 30.5°F.

Wind direction - West South West - South West

" Velocity - 7-8 miles per hour

Sky - Cloudy

Rainfall - nil during exposure or previous 24 hours

d. Field Results:

1. Observations on travel of phosgene vapor.

Direction of drift given by means of some N.P. shell fired at beginning and end of shoot give main drift slightly north of east.

Phosgene detected by odor and paper 1600 yards and 1800 yards from trenches. Limit of detection by odor and paper - 2250 yards from trenches.

2. Concentrations of phosgene:

Position number (see dia- gram in original report)	Time after burst of first shell when sample was taken	Height above floor trench at which sam- ple was taken		CONCENTRATION		
	min. Sec.	Ft. Inches	Mg./liter	Volume of air containing 1 vol- ume of phosgene both at N.T.P.		
5	3	30	4	nil.		
10	"	"	0			
14	"	"	"	1.15		
15	"	"	"	1.58		
17	"	"	1	1.94		
21	"	"	4	0.15		
21	"	"	"	0.46		
27	"	"	1	0.88		
6	4	40	"	0.88		
3	4	45	"	9.10		
4	"	"	1	0.36		
9	"	"	4	2.59		
13	"	"	"	12.81		
17	"	"	1	4.87		
20	"	"	4	47.49		
25	"	"	"	0.31		
28	"	"	1	0.68		
7	6	5	"	3.50		
8	"	"	4	0.20		
12	"	"	1	39.20		
16	"	"	"	1.45		
19	"	"	4	3.36		
24	"	"	"	27.35		
29	"	"	"	0.69		
29	"	"	"	0.65		
1	8	0	1	0.77		
2	"	"	4	0.68		
10	"	"	1	0.14		
11	"	"	"	0.10		
15	"	"	4	0.12		
18	"	"	"	2.29		
22	"	"	1	0.61		
22	"	"	4	11.32		
23	"	"	1	0.87		
23	"	"	8	0.22		
30	Shelter dugout	"	4	0.45		
31	Deep dugout	"	1	8 above floor of dug- out	8.17	10000
32	Shelter dugout	"	"	2.86	550	
				0.42	2500	
					11000	

See diagram in original report for location of animals and containers.

e. Toxicological Results

Position	No. of goats used	CASUALTIES			PERCENTAGE		Remarks
		Dead in 48 hours	Severe Class A or B	Light Class C	Dead	Severe casual- ties in cluding dead	
Intrench	6	5	5	0	50	100	Of 7 rats 6 died
In dugout	1	1	0	0	100	100	1 rat died
In open at 50 yards	5	0*	0	5	0	0	Of 5 rats 0 died
In open at 75 yards	3	0	0	1	0	0	" 4 " 1 "
In open at 100 yards	2	0	0	0	0	0	" 3 " 0 "
In open at 150 yards	0	-	-	-	-	5	" 0 "

These figures exclude those animals which were wounded in shell fire.

\*Diagram shows goats #10 in the 50 yard as dead within 48 hours. The animal died mainly as result of septic inflammation of the legs - its lungs were classed C.

\*\*Note: Rats were probably used as controls in these tests.

No. of Experiment	1	2	3	4
Date	April 25, 1917	Sept. 24, 1917	Oct. 14, 1917	Jan. 4, 1918
Time of day	8 P.M.	5:40 P.M.	4:50 P.M.	3:30 P.M.
No. of 4.5" howitzer	2	2	2	2
Range in yards	1750	1750	1750	1750
Front engaged, yards	20	30	30	40
Number of rounds	25	53	42	58
Duration of firing	4 Min. 0 Sec.	4 min. 30 Sec.	4 Min.	9 min.
Line velocity miles per hour	6-10	1-3	0-1	7-4
Temperature °F. Wet bulb	45	56.5	43.5	31.5
Dry "	49.7	58	44.0	31.5
Ground	-	50	36.5	30.5
Percentage of goats in trench				
Killed	28	89	100	50
Killed and severe casualty	-	100	100	100

Hour of Experiment	1	2	3	4
Percentage of goats in dugout				
killed	-	0	100	100
Killed and severe casualty	-	100	100	100
— goats in open at 50 yards				
killed	-	75	0	0
Killed and severe casualty	-	100	0	0

f. General Conclusions:

1. Rigid conclusions regarding effect of low temperature impossible from comparing trial #6 with 2 and 3 because of other factors which largely influence the results.

2. Percent of deaths in relation to temperature.

In trench - 50% in trial 2 same order as in 3.  
 50 yards - greater in trial 2 although temperature  
 10° higher than in trial 3.  
 In trench - trial 3 double trial 6 when temperature  
 was 10° lower.

3. Wind velocity as a factor.

Percent deaths should have greatest in trial 3,  
 less in trial 2, least in trial 6.  
 (a) In trench - order as expected less in trial 2,  
 least in trial 6.  
 (b) In open - greatest in trial 2 - accounted for by  
 gas being slowly carried over the  
 animals - no drifting.

4. Conclusions:

At temperatures between 32° and 56°F. shell filled with phosphogene can be used with good effects in winds up to 7 miles per hour and that maximum effect will be exerted in winds of very low velocity and also definite direction.

21. C.C.P. 74.

Report on the correlation of the physiological and chemical data obtained in 8 artillery field experimental trials with phosgene.

a. Method

Ordinary fire trench used.

Physiological Data:

Sheats were used and results tabulated as follows:

Deaths (include all animals killed during shoot).  
Severe casualties.

Light casualties.

Chemical Data (Material tabulated and some observations on same).

Time of exposure - total time occupied by shoot.  
persistency of phosgene very slight.

Concentration - general average - G.A.C., approximate concentration of gas existing for the total period of the shoot in that particular portion of the trench where an animal was exposed.

Principles considered -

1. Number of samples taken during shoot - 30-50,  
opened in several series, 4-5, during shoot.

Time of firing - dependant on judgement of officer in charge samples from all parts of trench; general average of these unsatisfactory due to uneven distribution of gas in trench.

2. Found that traverses of trench from natural sectors, concentration of gas uniform throughout sector.

3. Unnecessary to discriminate between samples 4 ft. and 1 ft. 8 in. above the trench floor.

4. Concentration omitted immediately after shell burst accidentally within trench - raise local concentration temporarily above general average.

5. Results of field tests found to check very well with chamber experiments.

This report covers the following trials:

Trial No.	1	2	3	4	5	6	7	8
Trial Date	9-24-17	10-14-17	1-4-18	1-12-18	3-9-18	3-13-18	4-5-18	4-8-18
Reference	GCP 2463	GCP 2735	GCP	GCP	GCP	GCP	GCP	GCP
			: 3670	: 3370	: 3993	: 4021	: 4262	: 4262

Example of G.A.C. calculation - concentration as volume of air containing 1 volume of phosgene. (changed to mg./l.)

Number	Sector (number: of sampling positions in brackets)	Time after zero at which samples were taken	Shell bursts in trench	Total time of shoot
1 (1 - 8)		: 0.3397 : 0.1920 : 0.6308		
	: nil	: 2.4553 : * : *		: 1(36.8166)
		: 8.832	: 0.6308	
2 (9 - 16)		: 1.104 : 12.617 : 1.472 : 0.1162		
	: 1.471	: 4.6434 : 0.8029 : 0.5838	: 1(46.434)	: 9'0"
		: 1.766	: 2.808	
3 (17- 23)		: 0.1472 : 0.2944	: 0.2105	
	: 0.4416	: * : *	: 0.5888	: 1(25.9764)
		: 0.8832	: 0.8832	
			: 11.0400	
4 (24 - 29)		: 0.8832 : 0.6793 : 0.6793 : 0.4416		
		: 8.3969	: 0.6308	
			: 0.739	

Table 2 Correlating physiological and chemical data for 8 phosphorus artillery shoots. Concentrations in  
Mg/liter.

No. of time : ; sector concentration shoot:	Sector concentration					Shell bursts: Actual casualties, sectors					
	1	2	3	4	5	in trenches	1	2	3	4	5
1	4°30'	1.920	5.600	12.944	:	X(20.0727)	3 D	3 D	2 D	:	:
2	4°0'	3.154	9.200	5.600	:	X(27.6)	nil	3 D	3 D	3 D	:
3	9°0'	1.92	X2.76	11.04	1.077	X(36.8)(1)	1 D	1 D	1 S.O.	:	:
4	6°10'	0.177	0.402	0.512	X0.158	0.0736	X(26.9)	1 LEU	1 S.O.	1 D	1 D
5	2°16'	1.104	0.0315	0.631	X0.981	2(11.04)	2 LEU	2 LEU	1 S.C.	1 S.C.	1 S.C.
6	11°0'	0.402	2.103	0.512	0.039	0.056	nil	1 D	2 D	1 D	1 S.O. 3 LEU
7	2°40'	0.147	2.103	2.456	0.188	0.981	nil	1 S.C.	2 D	2 D	1 LEU
8	2°50'	0.110	0.920	2.324	1.262	:	X(16.36)(2)	2 LEU	1 D	2 S.C.	1 S.O. 11 S.O.
							X(21.03)(4)	1 S.O.	1 S.O.	1 S.O.	:

L-shell burst; D-animal killed during shoot; S.C.-severe casualty; LEU-light casualties and animals not gassed.  
S.O. Concentrations calculated by method 1.

Groups of results from experiments -

- I Mainly deaths with some severe casualties, but no light casualties or unaffected.
- II Mainly severe casualties together with a few deaths on the one hand, and some light casualties or unaffected on the other hand.
- III Mainly light casualties and unaffected, with some severe casualties but no deaths.

Summary of results by groups -

Group	Deaths	Severe casualties	Light casualties, or unaffected
I	26	8	0
II	4	6	2
III	0	4	12

Table 2. R<sub>c</sub> Calculated by method 2, in mg./l.

No. of shoot:	Time	Sector concentration					Shell bursts in trench	Actual casualties, sectors				
		1	2	3	4	5		1	2	3	4	5
1	4'30"	2.944	3.68	3.154			(20.07272)	3 D	3 D	2 D		
							2(27.6)			1 S.C.		
2	4'0'	3.397	9.012	3.154			nil	3 D	3 D	3 D		
							(36.8(1))					
3	9'0'	1.162	3.154	1.338	1.003		3(46.5(2))	1 D	P 1 D	1 S.C. 2 S.C.		
							2(28.4(3))					
4	6'10"	0.147	0.405	0.736	1.194		(26.9)	1 L&U	1 S.C.	1 D	1 D	
							2(11.04(4))		2 L&U	1 S.C.	1 S.C.	
5	2'10"	1.472	0.315	0.589	0.589		1(27.8(4))	2 L&U	2 L&U	1 S.C.	1 S.C.	
										1 L&U		
6	11'0"	3.397	1.040	0.491	0.059	0.063	nil	1 D	2 D	1 D	1 S.C.	3 L&U
											1 L&U	
7	2'40"	1.766	1.766	1.623	2.760	0.960	nil	1 S.C.	2 D	2 D	1 S.C.	1 S.C.
											1 S.C.b	
8	2'50"	0.631	0.350	2.208	1.162		(16.86(2))	2 L&U	1 D	2 S.C.	1 S.C.	
							2(21.03(4))		1 S.C.			

N.B. Numbers in brackets are sector-numbers. D=animals killed during shoot; S.C.=severe casualties; L&U=light casualties and animals not gassed.

## Summary of results, grouped.

Group	Dorths	Severe casualties	Light casualties and unaffected
I	21	7	0
II	9	5	2
III	1	6	12

See plotted results -

## Conclusions-

- Close concordance between chemical and physiological data.
- Indicative of reliability of methods-field experiments in agreement with chamber experiments.
- Method of calculating G.A.C. reliable, method 1 more accurate.

# - zero time taken from burst of first shell.

\* - Indicates direct hit in sector of trench at time stated.

General average concentration for period of shoot calculated and stated  
for each sector.

Sector	G.A.C. Mg./L.	Shell bursts not included in G.A.C.	Total time period of shoot
1	1.920	35.8166 mg./l.	
2	2.760	46.484 "	
3	1.840	25.9764 "	9' 0"
4	1.077	-	-

Table No. 1

Report No.	1	1	2	3	4	5	6	7	8
Calibre	14.5"	14.5"	14.5"	16"	14.5"	14.5"	14.5"	14.5"	14.5"
Data	: Sept. 24 : Oct. 14	: Jan. 4,	: Jan. 12,	: Mar. 9 : Mar. 13	: Apr. 4, : Apr. 8				
	: 1917	: 1917	: 1918	: 1918	: 1918	: 1918	: 1918	: 1918	: 1918
Reference	: G.C.P.	: G.C.P.	: G.C.P.	: G.C.P.	: G.C.P.	: G.C.P.	: G.C.P.	: G.C.P.	
	: 2463	: 2735	: 3670	: 3370	: 3993	: 4021	: 4262	: 4262	
Dated	: Oct. 2, : Nov. 11	: Jan. 3,	: Jan. 30,	: Mar. 4,	: Apr. 6,	: May 2,	: Apr. 8,		
	: 1917	: 1917	: 1918	: 1918	: 1918	: 1918	: 1918	: 1918	
File No.	: XLIII, 29	: XLIII, 34	: XLIII, 44	: XLIII, 41	: XLIII, 53	: XLIII, 54			
Shell type	: C.I.	: C.I.	: C.I.	: C.I.	: C.I.	: C.I.	: C.I.	: C.I.	
	: Mk. V	: Mk. X	: Mk. X	: Mk. X	: Mk. X	: Mk. X	: Mk. X	: Mk. X	
Burster	: 21 dr.	: C.L.C.	: C.I.C.	: C(b)	: 1 smoke	: C.I.C.	: C.L.C.	: C.I.C.	
	: trotyl	: (a)	: (a)	:	: pellet	: (a)	: (a)	: (a)	
No. rounds	: 58	: 62	: 58	: 22	: 51	: 59	: 50	: 50	
Front yards	: 30	: 30	: 40	: 40	: 40	: 40	: 40	: 40	
Time taken	: 4'30"	: 4'0"	: 9'0"	: 11'0"	: 6'10"	: 2'18"	: 2'40"	: 2'50"	
Range yards	: 1750	: 1750	: 1750	: 4000	: 1750	: 1250	: 1750	: 1750	
Temperature°	:	:	:	:	:	:	:	:	
wet bulb	: 55.5	: 43.5	: 51.5	: 37	: 40	: 45	: 49	: 44	
dry "	: 53	: 44	: 32.5	: 33	: 43	: 47	: 54	: 43	
ground	: 50	: 35.5	: 30.5	: 35	: 38	: 45	: 50	: 44	
Wind velocity: 1-3	: 0-1	: 7-4	: 7-4	: 3-1	: 6-8	: 4	: 5-6		
Conditions	: clear	: humid	: cloudy	: cloudy	: blue sky	: blue sky	: cloudy	: cloudy	

(27.55)

22. C.C.P. 216. (C.W.C. 78).

Report on firing trial of 4.5" cast iron howitzer shell  
filled with phosgene.

a. Method:

Time - October 14, 1917 - 4:50 P.M.

Artillery:

Map range - 1750 yards - Front engaged 30 yards  
Effective area 30x30 yards - Rounds fired 42  
Rounds in effective area 27

" " " " from range table 29  
Rate of fire - battery fire 3 seconds  
Time taken to fire all rounds - 4 minutes

b. Meteorological Data:

Barometer - 29.46 inches  
Thermometer, wet bulb - 43.5°F.  
dry " - 44.0°F.  
ground - 36.5°F.

Wind - North, North East-North, North West  
velocity 0-1 miles per hour with period of  
complete calm.

Sky - Blue, cloudy  
Rainfall - nil. during experimental, 0.01 inches during  
previous 24 hours.

c. Field Results:

Detected 1200 yards South East of trenches by odor and paper.  
 " 400 " North " " " "

Position Number (see ori- ginal re- port)	Time after burst of first shell when sample was taken	Height above floor of trench at which sam- ple was taken	Concentrations			
			Min. Sec.	Ft. Inches	Mg./liter phosgene	Volume of air containing one volume of phos- gene both at N.T.P.
5	1	0	4	0	4.12	1100
5	"	"	1	8	5.05	896
9	"	"	4	0	4.48	826
12	"	"	"	"	4.69	965
18	"	"	"	"	0.24	18900
4	2	0	0	"	5.27	859
8	"	"	"	"	13.16	344
10	"	"	"	"	10.59	426
11	"	"	"	"	6.06	747
13	"	"	"	"	5.74	789
14	"	"	1	8	trace	-
17	"	"	4	0	1.21	3740
2	2	50	"	"	2.30	1970
4	"	"	"	"	1.65	2740
7	"	"	"	"	5.92	765
7	"	"	1	8	22.01	206
14	"	"	4	0	10.76	420
16	"	"	"	"	trace	-
1	3	45	"	"	0.08	56600
1	"	"	1	8	4.50	1010
3	"	"	4	0	1.77	2560
6	"	"	"	"	4.24	1070
15	"	"	"	"	4.23	1070
19	"	"	"	"	8.26	548
20 dugout	"	"	1	8 above floor of dugout	trace	-
21	"	"	1	8 "	50.48	149

d. Toxicological Results:

Arrangement of animals shown in diagram - see original report.

Position Gouts	No. used	Casualties			Percentage		Remarks
		Dead in 48 hrs.	Severe class A or B	Light Class C	Dead	Severe casualties including deaths	
In trench	9	9	0	0	100	100	Of 9 rats 9 died
In dugout	1	1	0	0	100	100	One rat died
In open at							
50 yards	4	0	0	3			Of 5 rats 5 died
In open at							
100 yards	3	0	0	2	0	0	Of 3 rats none died

Of the 10 dead animals, 9 died within 16 hours and the other soon afterwards. Greater humidity of atmosphere may cause decomposition of phosgene, so that the sphere of lethal travel is restricted.

e. REMARKS:

Concentration higher than in G.C.P. 2463. The figure 1/149 in dugout at 3 minutes-45 seconds is highest yet recorded.

## 23. C.C.P. 106.

Report on firing trial of 6" O.I. howitzer shell filled  
phosgene.

a. Method

Time - Saturday, July 27, 1918 - 8:05 P.M.

Artillery Details

No. 6" howitzer used - 2

Type C.L. "O" No. of shell C. 589

Bursting charge C (b); propellant charge 2d. N.G.T.

Fuse 106 III. Blind shell - 0

Map range (yards) 4000 - target engaged 40x40.

Rounds fired (exclusive of ranges) 21 - rate of fire B.F. 15 sec/

Time taken to fire all rounds 4 minutes 20 seconds -

accuracy very good.

b. Meteorological Data

Barometer - 29.75 inches

Thermometer, dry bulb - 53°F.

wet " - 56°F.

ground - 54°F.

Wind - Variable, drift to dead calm.

Sky - Overcast.

Rainfall - nil. during experiment - 0.04 in. during previous 24 hours.

General Conditions - very favorable, muggy and misty after warm afternoon - grass very damp from previous rain.

c. Field Results: Analytical figures.

Sample	No.	Phosgene calculated from		True phosgene value	
		total chlorine mg./liter	volumes of air containing 1 volume of phos- gene.	mg. per liter	Volume of air containing 1 volume of phos- gene.
Samples opened near square	1	0.25	15000	0.13	35000
15 minutes after end of shoot	2	0.19	25000	0.13	35000
Samples opened 860 yards from target	1	0.04	100000		
3/4 hour after end of shoot	2	0.04	100000		
	3	0.04	100000		
	4	0.04	100000		

4. Toxicological Results.

Guinea pigs - one pig on every 8 square yards in series  
in cages 4 feet above ground level.

Number exposed - 49 Number killed 49 Percent killed - 100  
Result due to blanketing effect of phosgene.

Travel of Vapor

1. 300 yards - from target - necessary to wear masks  
for 20 minutes.

2. Artillery trenches - 150 yards south.

20 goats and 20 rats in position.  
14 rats died, 5 goats light casualties.

3. Ford van containing 54 guinea pigs (Killed - 4  
(Gassed - 27  
200 yards from target - 10 min.  
860 " (third portion) - 39 min.  
lethal concentration phosgene 40 min.  
exposure, being 1/50,000.

24. C.C.P. 216. (5594)

Report on experiments to determine the concentration of gas produced in the open by the explosion of 4.5" howitzers cast iron shell filled with phosgene.

a. Object:

To determine concentration of phosgene at varying distances from point of shell burst.

b. Time of trial:

July 30, 1918 - 7:15 P.M.

c. Meteorological Data:

Barometer - 29.85 inches

Thermometer - dry bulb - 70°F.

wet " - 68°F.

ground - 69°F.

Wind direction - South South East

" velocity - 1st exposure -  $5\frac{1}{2}$  miles per hour

2nd " -  $5\frac{1}{2}$  " " "

Sky - blue

Rainfall - nil. during exposure or previous 24 hours

Weather - fine

EXPERIMENT NO. I: 1 shell exploded at rest in open.

a. Method: Observers under cover 15 yards down wind from point of burst, immediately after explosion emerged and took sample from jets breast high - 15 yards from point bursting shell.

A visible cloud was formed which moved quickly down wind. Doubtful whether any other than first samples were taken in main cloud as wind velocity was rather higher.

b. Field Results:

Observer No.	Sample No.	Time after explosion of shell at which sample was taken	Concentration		Volume of air containing one volume of phosgene both at N.T.P.
			HC./liter	phosgene	
1	1	Approximately 5 sec.	0.34		13000
	2	" 7 "	0.38		12000
	3	" 9 "	0.32		14000
2	4	" 5 "	2.64		1700
	5	" 7 "	0.46		10000
	6	" 9 "	0.98		4600
3	7	" 5 "	2.04		2200
	8	" 7 "	0.08		60000
	9	" 9 "	trace		

It is considered that concentration shown by 4 and 7 are representation of main cloud.

EXPERIMENT NO. II.

a. Method: 3 shells in line at intervals of 1 yard in open and exploded simultaneously.

b. Field Results:

Observer Number	Sample Number	Distance from point of burst of shell yards	Time of explosion of shell at which sample was taken Seconds	Concentrations	
				Mg./liter phosgene	Volume of air containing one volume of phosgene both at N.T.P.
1	1	15	Approximately 5	0.08	60000
	2	"	" 7	3.67	1200
	3	"	" 9	0.97	4700
1a	4	"	" 5	1.69	2700
	5	"	" 7	1.28	3500
	6	"	" 9	1.60	2800
1b	7	"	" 6	4.50	1000
	8	"	" 7	2.66	1700
	9	"	" 9	2.86	1600
2	10	25	" 11	1.04	4400
	11	"	" 13	0.95	4900
	12	"	" 15	0.72	6900
2a	13	"	" 11	1.31	3600
	14	"	" 13	1.21	3700
	15	"	" 15	0.81	6000
2b	16	"	" 11	3.93	1200
	17	"	" 13	1.54	2900
	18	"	" 15	0.66	7000
3	19	50	" 25	2.49	1800
	20	"	" 27	2.16	2100
	21	"	" 30	1.66	2700
3a	22	"	" 25	2.53	1800
	23	"	" 27	1.43	3200
	24	"	" 30	1.26	3600
3b	25	"	" 25	1.60	2800
	26	"	" 27	1.48	3100
	27	"	" 30	1.43	3200

d. Remarks:

Eliminating sample No. 1 which was obviously out of  
the cloud.

General Average Concentration

Distance	G.A.C.	Highest Concentration at the distance
15 yards	1/1900	2.824 mg./l.
25 "	1/3400	1.2988 "
50 "	1/2500	1.766 "

e. Summary of Results:

- I. Where one 4.5" howitzer cast iron - concentration 1/2000 at 15 yards, 2.208 mg./l.
- II. Where three 4.5" howitzer cast iron - concentration 1/1000, 1/1200, 1/1800, etc., distance 15, 25, 50 yards, 4.416, 3.68 and 2.453 mg./l.  
General average concentration - 1/1900, 1/3400, 1/2500, 2.824,  
1.2988 and 1.766 mg./l.

25. C.C.P. 216. (1398)

Report on experiments with C.I. 4.5" howitzer shell  
Mark I, filled phosgene.

EXPERIMENT NO. I.

a. Method:

Time of firing - April 26, 1917 - 8:10 P.M.

ARTILLERY DETAILS:

10 shells fitted with #18 electric fuses, 2 rows - one  
10 yards, 2nd 11 yards from trench shells, 2 yards apart in each row.

No. 1 failed to explode.

b. Meteorological Data:

Barometer - 30.20 inches

Thermometer - wet bulb  $\pm$  45.5° F.  
dry "  $\pm$  51.5 F.

Wind direction  $\pm$  North East

" velocity - 6 miles per hour

Sky - clear, blue

Rainfall - Nil during experiment or during previous twenty  
hours.

c. Field Results:

SAMPLES TAKEN FIVE SECONDS AFTER EXPLOSION ON PARAPET OF TRENCH.

Position	f	Concentrations	Volume of air containing
Number	mg./liter		one volume phosgene both at
(see ori-			N.T.P.
ginal dis-			
stan			
1	0.24		18900
2	11.51		400
3	16.97		267
4	20.84		217
5		Bottle broken by shell splinters.	

Position Number (see ori- ginal report diagram)	Time after explosion of shell	Height above bottom of trench at which sample was taken	Concentrations		Volume of air contain- ing one volume phosgene both at N.T.P.
			Mg./liter	Min. Sec. Pt. Inches	
1	10	4 6	trace		-
1	15	3 6	"		-
1	20	2 6	"		-
1	30	1 6	"		-
1	45	1 8	0.08	55600	
1	1 0	1 8	0.08	55600	
1	1 15	" "	trace	-	
1	1 30	" "	nil.	-	
2	10	4 6	6.25		723
2	15	3 6	2.94		1540
2	20	2 6	1.55		2920
2	30	1 6	0.90		5030
2	45	1 8	0.31	14600	
2	1 0	1 8	0.91		4980
2	1 15	" "	0.28		16200
2	1 30	" "	0.36		12600
3	10	4 6	16.83		269
3	15	3 6	18.20		249
3	20	2 6	11.40		397
3	30	1 6	6.37		711
3	45	1 8	0.52		14200
3	1 0	" "	0.47		9630
3	1 15	" "	0.32		14200
3	1 30	" "	0.24		18900
4	10	4 6	11.16		406
4	15	3 6	12.07		375
4	20	2 6	12.73		356
4	30	1 6	11.31		400
4	45	1 8	7.10		638
4	1 0	" "	0.75		6040
4	1 15	" "	0.31		14600
4	1 30	" "	0.27		16800
5	10	4 6	3.87		1170
5	15	3 6	6.22		728
5	20	2 6	4.59		938
5	30	1 6	15.33		295
5	45	1 8	4.77		949
5	1 0	" "	1.25		3620
5	1 15	" "	0.88		5140
5	1 30	" "	trace		-

Position Number	Time after explosion Min. Sec.	Height above bottom of trench	Mg./liter phosgene	Volume of air contain- ing one volume phosgene at N.T.P.
1	30	1 ft. 8 in. above floor level of dugout capacity	0.08 trace	56600
1	30	1272 cubic feet	0.19	23800
3	30	floor of dugout	trace	-
4	30	21 ft. 6 in. below ground level	0.08	56600
6	0		0.08	56600

d. Remarks

1. Concentration in trench high for 30-45 seconds - then rapid fall surprising low.

2. Established point that phosgene can be liberated from explosion of cast iron artillery shell in such a manner as to sink into trench. Probably concentration could not be as great in actual artillery fire.

EXPERIMENT NO. II.

Trial of the effect in animals in trench by 4.5" howitzer cast iron shell, filled with phosgene when fired from gun.

a. Methods

Time of trial - Wednesday, April 25, 1917 - 8:00 P.M.

Artillery details

No. and type of guns - Two 4.5" howitzer

Average weight of shell 34 lbs. 6 ozs.

Propellant charge - 1st charge

Fuse 44 Mark III - XA

Blind shell - 1

Bursting charge - 5 drams trotyl

Max range 1750 yards - front engaged 20 yards

Effective area 20 x 30 yards - rounds fired 25

Rounds in effective area 13 - rate of fire 3 rounds -

B.F. 2 seconds with pauses

Time taken to fire all rounds - 4 minutes

Accuracy of shooting - good

b. Meteorological Data:

Barometer - 30.2 inches

Thermometer - wet bulb - 45° F.

dry " - 49.7° F.

Wind velocity - 5-10 miles per hour

" direction - North East

Sky - Overcast

Rainfall - Nil during exposure & previous 24 hours.

c. Toxicological Results (See diagram in original report).

	No. in trench	Dead within 24 hours	Dead within 48 hours	Dead within 72 hours	Total dead	Percentage dead
Goats	7	2	-	-	2	28
Rabbits	7	-	-	-	0	0
Rats or Mice	8	4	2	-	6	75

d. Remarks:

Wind unsteady - most part velocity 5 miles per hour  
frequent gusts .10 miles per hour on 20 yard front - 25 - 4.5" howitzer  
shell are required.-each holding 944 cc. of liquid.

26. O.C.P. 216. (4202)

Report on firing trials of 4.5" howitzer C.I. mark X shell filled with phosgene.

a. Object

To study effects with lower wind velocity - compare report 4021. Previous results had shown that effects produced were only slight at this velocity.

b. Method

Artillery Details

No. of trial	13	14
No. of 4.5" howitzers used	6	6
Type of shell	C.I. Mark X	C.I. Mark X
Map range - yards	1750	1750
Front engaged - yards	40	40
Effective area	40 x 30	40 x 30
Rounds fired (ranges not included)	50	50
Rounds in effective area	27	33
Predicted ditto	34	34
Rate of fire	gun fire	Section fire 10"
Time taken to fire all rounds	2'40"	2'50"
Direction of fire	enfilade	frontal
Accuracy of shooting	good	very good
Bursting charge	C.I.Q. (a)	C.L.Q. (a)
Propellant "	2d	2d
Fuse	106 Mk. III	106 Mk. III
Blind shell	0	0

c. Meteorological Data

No. of trial	13 - Apr. 5, 1918	14 - Apr. 6, 1918
No. of 4.5" Howitzer	6:40 P.M.	7:00 P.M.
Barometer inches	29.73	29.35
Thermometer dry bulb	54°	48°
wet "	49°	44°
ground	50	44
Wind direction	West North West	North North East
velocity	mainly	North East
Sky	4	3 - 6
Rainfall - during experiment	blue - cloudy	Blue - cloudy
during previous 24 hours	nil.	nil.
General conditions	trace	0.01 inches
	very favorable	favorable

d. Toxicological Results:

1. Observations on Travel of Phosgene Vapor.

Trial 13:

1760 yards from trenches - detected by slight lacrimation and test paper (burned paper yellow).

2300 yards from trenches - limit beyond which not detected.

Trial 14:

1760 yards from trenches - detected by strong odor - no lacrimation.

2200 yards from trenches - traces detected by smell - no indication on paper.

2. Physiological Details:

See original report for arrangement of animals.

Trial 13. Goats:

Position	No. of goats used	Casualties			Percentages	
		Dead in 48 hours	Severe Class A or B	Light Class C	Dead	Severe casualties including dead

In trench	8	4	4	0	50	100
In open at 50 yards	5	0	1	1	0	20
In open at 75 yards	4	0	0	0	0	0
In open at 100 yards	3	0	0	1	0	0

<u>Trial 14 Goats:</u>						
Position	No. of goats used	Dead in 48 hours	Severe Class A or B	Light Class C	Dead	Severe casualties including dead
In trench	7	1	4	2	14	71
In dugout	1	0	0	0	0	0
In open at 50 yards	4	0	0	2	0	0
In open at 75 yards	4	0	0	1	0	0
In open at 100 yards	3	0	0	1	0	0

<u>Trial 13 Rats:</u>						
Position	No. of rats used	Dead in 48 hours	Severe Class A or B	Light Class C	Dead	Severe casualties including dead
In trench	8	7	0	1	87	87
In open at 50 yards	2	1	1	0	50	100
In open at 75 yards	3	0	0	3	0	0
In open at 100 yards	1	0	0	1	0	0

Position	No. of goats used	Casualties			Percentages	
		Dead in 48 hours	Severe Class	Light Class	Dead	Severe casualties including dead
		A or B	C			
In trench	7	6	0	1	86	86
In open at 50 yards	5	2	1	2	40	60
" " " 75 "	4	1	1	2	25	50
" " " 100 "	3	1	0	2	53	53

N.B. - In trial 13, due to slight wind change from that prevailing when animals were placed in position the majority in open were not in direct path of the cloud.

#### e. Field Results

Position number see original diagram	Time after explosion of first shell at which sample was taken	Height above floor of trench at which sample was taken	Mg./liter phosgene	Volume of liquid filling one volume per cubic meter of air containing phosphogene at N.T.P. sample		
				Min.	Sec.	Ft.
						Inches
1	20	4	0	trace	-	-
3	"	1	8	"	-	-
7	"	4	0	0.22	20000	0.154
12	"	"	"	trace	-	-
16	"	"	"	3.78	1200	2.640
19	"	1	8	1.23	3700	0.859
23	"	4	0	14.12	520	9.860
24	"	1	8	1.23	3600	0.873
25	45	1	0	trace	-	-
26	"	1	8	0.20	25000	0.140
27	"	4	0	4.76	1000	3.324
28	"	"	"	nil.	-	-
29	"	1	8	1.69	2700	1.180
30	"	4	0	5.13	900	3.580
32	"	1	8	1.58	2900	1.110
34	"	4	0	2.93	1500	2.046
37	"	"	"	1.06	4300	0.740
38	50	"	"	0.53	9000	0.370
39	"	"	"	3.59	1200	2.507
40	"	1	8	4.72	1000	3.296
41	"	4	0	nil.	-	-
42	"	"	"	0.08	600000	0.056
43	"	"	"	0.88	5000	0.615
44	"	"	"	0.88	5000	0.615
45	"	4	0	0.56	8000	0.405
46	"	"	"	1.55	2900	1.082
47	"	4	0	2.17	2100	1.516
48	"	"	"	1.89	2400	1.320
49	"	1	8	1.60	2600	1.118

Position number	Time after explosion	Height above floor of trench at which sample was taken	Mg./liter	Volume of air containing one volume phosgene both at N.T.P.	Liquid filling phosgene in ccs. per cubic meter of sample
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	Min.	Sec.	Feet	Inches
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16	2	40	1	8	nil.	-	-
18	"	"	4	0	trace	-	-
21	"	"	"	"	0.56	6000	0.391
21	"	"	1	8	0.56	8000	0.391
26	"	"	4	0	0.22	20000	0.154
28 dugout	"	"	1	8	nil.	-	-
29	"	"	"	"	"	-	-

Sector	Samples	General Average Concentration - Volumes of air containing one volume of phosgene both at N.T.P.	Time of shot
1	1-4	50000*	
2	5-11	2100	
3	12-20	1800	
4	21-25	2800	2 Mins. 40 Secs.
5	26-27	4500	

\*-Shell burst very close to trench at end of shoot which may have given high late concentration. G.A.C. for whole period - 5000.

## Trial 14.

Position Number (see ori- ginal report diagram)	Time after explosion of first shell when sample was taken	Height above floor of trench at which sample was taken	Mg./liter phosgene	Volume of air containing 1 volume phos- gene both at N.T.P.	Liquid fill- ing phosgene in cu. per cubic meter of sample.
	Min. Sec.	Feet Inches			
5	25	4 0	nil.	--	-
10	" "	"	0.84	5000	0.587
11	" 1	8	1.28	5500	0.894
15	" 4	0	0.55	8000	0.384
20	" 1	8	0.24	19000	0.168
21	" 4	0	0.89	5000	0.622
27	" 4	0	0.40	11000	0.279
4	20	"	nil.	-	-
17	"	1	0.24	19000	0.168
9	"	1 4	1.03	4400	0.719
19	"	0 0	trace	-	-
23	"	8 0	8.90	500	6.216
26	"	1 4	1.96	2300	1.359
28	"	1 4	1.50	3000	1.047
53*	"	"	nil.	-	-
54*	"	"	0.89	12000	0.272
55*	"	"	0.18	25000	0.126
2	"	"	nil.	-	-
5	"	"	0.82	14000	0.224
6	"	"	0.51	15000	0.217
12	"	"	0.75	6000	0.524
16	"	"	0.52	9000	0.363
20	"	"	0.78	6000	0.545
22	"	"	0.76	6000	0.531
29	"	"	1.36	5300	0.950
6	"	"	0.18	25000	0.126
7	"	"	nil.	-	-
18	"	"	0.12	40000	0.084
14	"	"	0.26	17000	0.182
18	"	"	2.90	1600	2.025
25	"	"	0.12	40000	0.084
23	"	"	4.52	1000	3.017
28	"	"	4.74	1000	3.311
23	"	"	1.92	2400	1.341
30	Shelter dugout	"	0.68	7000	0.476
31	Deep dugout	"	trace	-	-
32	Shelter dugout	"	0.16	30000	0.112
12	Unknown	4 0	0.91	5000	0.635
24	"	"	16.67	271	11.640
			21.63	207	15.250

\* Samples taken 50 yards from trench at 1 ft. 8 inches above ground level.

Trench Sector	Sample numbers	Time of shoot in sector	General stated as volumes of air con- taining one volume phosgene	Average Concentration	Shell burst con- centration not includ- ed in sector figures
1	1-8	2 Min.	40000	0.1104 Mg./l.	
2	9-17	50 Sec.	4800	0.92 "	270 16.355 Mg./l.
3	18-25		1900	2.324 "	
4	26-29		3500	1.2617 "	210 22.03 "

Sectors 2, 3 and 4, which show the effective area covered by the cloud give a general average concentration of 2900., 1.5227 Mg./l.  
General average concentration for total period: 3800, 1.162 mg./l.

#### 2. General Remarks:

- variable wind.
1. Weather conditions - less favorable in trial 14 -
  2. Artillery - distribution better in trial 13 than in trial 14 because Northern end of target received much less attention than Southern end. No. of shells fell short.
  3. Concentrations phosgene - not so high in 14.
  4. Animal casualties - high percent deaths and severe casualties - localized in trench.

#### 5. Conclusions:

1. A surprise shoot with 50 rounds on 40 yards at 1750 yards map range may be expected to render majority of occupants of target either deaths or severe casualties.
2. Require very accurate shooting and favorable weather. Most favorable wind 4 miles per hour or under.

27. O.W. & 110.

a. Object.

To determine which is the most suitable nature of shell to employ for "surprise" shoots, 18 pr., 4.5", or 6" howitzers.

b. Meteorological Data.

Wind velocity -  $4\frac{1}{2}$  - 10 miles per hour

Ground temperature - Lower than air temperature  
(exact temperature not stated)

Weather conditions - generally favorable.

c. Field Tests:

Comparative firing trials of 18 pdr., 4.5" How., and 6" How. shell filled phosphene (p.9).

	Trial I			Trial II			Trial III		
	18 pdr.	4.5" How.	6" How.	18 Pdr.	4.5" How.	6" How.	18 Pdr.	4.5" How.	6"
No. of guns or hows. used	4	4	2	4	3	2	4	3	2
Type of shell	C.I.	C.I. XI	C.I.	C.I.	C.I. X	C.I.	C.I.	C.I. X	C.I.
Bursting charge	Fuse only	(C.I.C.) (a)	C (b)	Fuse only	C.I.C. (a)	C (b)	Fuse only	C.I.C. (a)	C (b)
Fuse	106 III	106 III	106 III	106 III	106 III	106 III	106 III	106 IIIA	106 ZZZ
Max range in yards	4050	4050	4050	4050	4050	4050	4050	4050	4050
Target engaged	50x50	50x50	50x50	50x50	50x50	50x50	50x50	50x50	50x50
No. of rounds fired	70	35	17	43	25	10	29	23	9
Rate of fire	B.F. 1 sec.	B.F. 3 sec.	B.F. 10 sec.	3rds. G.F. 2 sec.	B.F. 2 sec.	B.F. 15 sec.	B.F. 3 sec.	B.F. 3 Sec.	B.F. 15 sec.
Time taken to fire all rounds	4 min. 2 sec.	4 min. 3 sec.	2 min. 57 sec.	1 min. 35 sec.	1 min. 45 sec.	2 min. 15 sec.	2 min. 20 sec.	1 min. 57 sec.	1 min. 50 sec.
Accuracy of shooting	very good	excellent	poor	very good	good	very good	very good	good	good
Volume of phosphene used (liter)	34.3	29.3	37.3	22.	21	20	19.7	19.3	19.

**d. Toxicological Results**

Animals: Caged guinea pigs in each target at 10 yard intervals.

Calibre of gun	Litres of phosgene effective	<u>Casualties</u>		Proportional percentage of casualties per 10 liters phosgene taken in each case	
		Killed	Killed & gassed	Killed	Killed & gassed
I 18-pr.	24	14/34	24/34	17	29
	4.5"	4/29	21/29	8	42.5
	6"	5/29	23/29	26	27
II 18-pr.	9	2/34	3/34	5.8	10
	4.5"	1/35	3/35	2.0	6
	6"	1/36	6/36	7.5	11.5
III 18-pr.	12	3/32	8/32	7.7	20.8
	4.5"	12.5	4/33	10.5	30.0
	6"	15.0	21/36	32.0	59/7

**e. Conclusions:**

6" howitzer shell filled phosgene superior to either 18 pr. gun shell or 4.5" howitzer shell, filled phosgene under varying conditions of time and weather.

28. O.W.C. 51. C.L.P. 1453.

Use of chlorpicrin and phosgene mixtures in field gun and howitzer shell.

a. Method

Artillery Details

Shells - 4.5" Howitzer, steel, C.T.

Number of shells - 50

Filling - Chlorpicrin 75% - Phosgene 25%

Front engaged - trench, 40 yards from four howitzers

Booster charge - 16 grams tetryl surrounded by paraffin wax

Fuse - No. 106

Time of firing - 4 minutes, 53 seconds

Shell falling in effective area - 23 out of 50.

b. Toxicological Results

Kind of Animals	No. in trench	Dead within 24 hours	Dead within 48 hours	Dead within 72 hours	Total dead	Percent dead
Goats	14	9	0	1	10	71
Rabbits	8	4	3	0	7	87
Rats	14	14	0	0	14	100

Two goats in a dugout - did not die within 72 hours, although 1 did so half a day later.

Pathological examination showed damage to lungs and blood, sufficient to render animals which live unfit for physical exercise.

c. Field Results

Mixture does not give adequate smoke for ranging purposes.

Criticism: The work on goats is reported in C.W.C. 77. The data given here is very meagre, especially that pertaining to meteorological conditions. Some additional data is given in C.W.C. 77 but whether or not this is applicable to the whole of this work is not known.

29. O.C.P. 217.

Report of firing trials of 4.5" howitzer shell filled with phosgene and chlorpicrin.

Trial No. 21.

a. Methods

April 26, 1917 - 6:45 P.M.

Artillery Details

Number and type of guns used, two 4.5" howitzer

Average weight of shell, 34 lbs. 8 ozs.

Map range, 1700 yards. Front engaged, 40 yards

Effective area, 40 by 30 yds. Rounds fired 70.

Rounds in effective area, 42.

Rate of fire, 3 rounds B.F. 2 seconds with pause

Time taken to fire all rounds, 10 minutes 25 seconds

Accuracy of fire, very good

Direction of fire, enfilade

Bursting charge, 5 drams T.N.T.

Fuse 44 Mark III x A

Blind shell - I

b. Meteorological Data

Barometer - 30.2 inches

Thermometer - wet bulb - 45.7° E.

dry " - 50.2° F

Wind direction - W.N.W.

velocity - 5 miles per hour

Sky - clouding over after fine day

Rainfall - none during test, or during previous 24 hours

c. Toxicological Results

Animals	No. in trench	Dead 24 hrs.	Dead 48 hrs.	Dead 72 hrs.	Total dead	Percent dead
Goats	13	7	-	-	7	54
Rabbits	14	-	1	-	1	7
Mice	11	10	-	-	10	91

d. Results

The results are attributed to:

1. Low bursting charge. The mixture was not sufficiently atomized.
2. Relative efficiency factor of clouds formed from the 4.5" C.I. shell, holding 625 cc. and the steel container holding 944 cc. The cast iron shell is not as efficient as the steel container.

Attention is called to the low mortality among the rabbits used.

Trial No. 31

a. Object

To get further information regarding rate of fire.

b. Method

April 26, 1917 - 8:00 P.M.

Artillery Details

No. and type of guns used, one 4.5" howitzer  
Average weight of shell, 34 lbs. 9.0 ozs.  
Propellant charge, 1st charge  
Bursting charge, 16 drams trotyl  
Map range, 1750 yards  
Front engaged, 50 yards  
Effective area, 20 x 30 yards  
Rounds fired, 23  
Rounds in effective area, 13  
Rate of fire, B.P. 30 seconds  
Time to fire all rounds, 13 minutes 36 seconds  
Fuse, 44 Mark III x 4  
Blind shell, 1  
Direction of fire - enfilade  
Accuracy of fire, very good

c. Meteorological Data

Barometer = 30.2 inches

Thermometer - wet bulb = 45.6°F.

dry " = 49.1°F.

Wind, direction - W. (unsteady)

velocity = 2 miles per hour

Sky, overcast, rainfall, none during experiment, or previous 24 hours.

d. Toxicological Results

Animal	No. in trench	Dead in 24 hrs.	Dead in 48 hrs.	Dead in 72 hrs.	Total Dead	Percent dead
Goats	7	7	-	-	7	100
Rabbits	7	4	1	-	5	71
Mice	7	7	-	-	7	100

e. Conclusions

13 shell fell in the effective area and 3 burst in a group south of effective area. These were effective because when they burst the wind had changed to southwest and the clouds formed were swept right along the line of the trench.

The shell did not give adequate smoke for ranging purposes.

The gas appeared to hang about the trench much more than in trial #2 and 15 minutes after firing had ceased there was still a distinct haze in the trench.

This was the slowest rate of fire so far tried and gave the best results with phosgene and chloropicrin and one of the best results recorded in any trial.

30. A.E.F. 176 (A.G.A. 77).

Persistency of a mixture of phosgene and chloropicrin liberated from artillery shell.

b. Method

Artillery Data

Shells: Steel, 4.5", container type

How fired: From four howitzers

Range: 2400 yards

Time to fire all rounds: 11 minutes

Collection of Samples: Samples of atmosphere  
in the woods, and in the open, where concentrations of chemicals were highest.

b. Meteorological Data

Wind velocity - 5 to 7 miles per hour.

c. Toxicological Results

1. Toxic Effects on Animals

Of six goats exposed and examined, two were found to be suffering from gas poisoning. The pathological examinations showed that three goats might be classed as light casualties.

2. Toxic Effects on Observers:

Strong lachrymation was experienced one minute after cessation of fire. Eight minutes after firing, lachrymation was experienced near the ground. 57 minutes after the last burst, the woods were free from vapors.

d. Conclusions

Much greater under surface persistency was to be expected in an area previously bombarded than in fresh soil. At least five days should elapse after bombardment with shell filled with chloropicrin and phosgene, before unprotected troops dig themselves in.

Criticism: P.G., the mixture used in these tests, is apparently a definite mixture but the proportions of phosgene and chloropicrin are not known.

51. Richter, Burrell, Clayton, Ogleasy, Kuhn.  
(P.T. VIII-1380)

Report on 50/50 mixture of chlorpicrin and phosgene  
fired statically from a Livens projectile.

a. Object

To determine the lethal area in trenches from detonations of Livens projectiles, containing 50 percent chlorpicrin and fifty percent of phosgene.

b. Method

Livens projectiles containing 12 liters of a mixture were fired statically in a trench. 6 oz. black powder used as booster. Eight dogs at 20 foot intervals on each of the projectile were exposed for thirty minutes.

Artillery Data:

Time of firing: 8:54 a.m. 12/6/18

Extent of gas cloud: 144 feet to left of projectile,  
80 feet to right of projectile.

Lethal area: 144 feet to left of projectile.

40 feet to right of projectile.

Separation of gases: After some distance, the phosgene was ahead.

c. Meteorological Data

Wind velocity: At time of firing, nil. Average for the first five minutes one mile per hour.

Temperature of air:

In trench - 53° F.

Ground in trench - 51.8° F.

Weather: Not given.

Relative humidity: 94%

Barometric pressure: 29.88 inches.

d. Field Results

Arrangement of samplers: Eight groups of ten samplers each were placed twenty feet apart for a distance of 100 feet, to the right and left of the projectile.

CONCENTRATIONS															
Concentration in Mg./l.					Concentration in Mg./l.										
Chlorine					Phosgene										
Intervals in Seconds					Intervals in Seconds										
10	30	60	180	300	10	30	60	180	300						
.00	.53	4.900	1.70	.00	.00	—	—	1.40	.00	.00	—	—	1.08	.00	
4.45	9.06	.91	.63	1.17	—	6.69	.64	.07	.23	—	—	6.69	.64	.89	1.54
10.73	10.15	1.55	.62	.57	11.20	—	1.09	.46	—	3.98	—	—	1.17	.45	—
8.48	8.39	5.65	5.22	3.80	7.03	7.38	—	5.20	3.18	5.22	4.69	—	2.25	2.31	—
2.76	—	6.36	.42	10.85	1.05	4.94	5.02	8.46	5.69	3.08	—	4.19	—	10.38	—
.42	—	.83	.98	2.92	—	.00	.64	—	1.20	—	—	.57	—	—	3.16
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.12
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

A large part of the cloud rolled out over the trenches, settled to the ground and advanced so as to fill the trench and on over the ground in an easterly direction. After four minutes this part of the cloud had advanced beyond the trench system. The main part of the cloud, according to the observation of the eye, climbed out of the trench 160 feet to the left, and 50 feet to the right of the projectile.

In this list it must be kept in mind that a higher concentration is generally realized in the part of the trench occupied by the dogs than at the top of the sample bottle.

After twenty minutes it was impossible for men to enter the trench without masks, within 50 feet to the right, and 150 feet to the left of the projectile. At this time the odor of phosgene, could still be distinguished, although that of chlorpicrin was still predominant.

After twenty-five minutes one could advance to the distance of fifteen feet from the crater, from the left side of the projectile and to the right to about 100 feet from the crater without appreciable discomfort.

#### e. Toxicological Results:

Position	Symptoms	Effects
160 feet, left	Lachrymation, depression, salivation	Severe casualty
140 "	" " "	
" "	trembling, rapid and shallow respiration	Death in 12 hours
120 "	Sneezing, lachrymation, salivation, increased nasal discharge, retching	Death in 12 hours
100 "	Salivation, lachrymation, retching, dyspnoea	Death in 5 hours
80 "	Salivation, lachrymation, nasal discharge, dyspnoea	Death in 12 hours
60 "	Lachrymation, salivation, retching, dyspnoea	Death in 12 hours
40 "	Salivation, lachrymation, retching vomiting, dyspnoea	Death during exposure
20 "	Wildly excited, salivation, lachrymation, vomiting, gasping	Death during exposure
20 feet right	Wildly excited, salivation, lachrymation, retching, vomiting	Death during exposure
40 "	Excitement, collapse, lachrymation, salivation, retching, vomiting	Death in 10 hours
60 "	Lachrymation, salivation, marked depression	Severe casualty
80 "	Lachrymation, salivation	Light casualty
100-160 feet	None	Unaffected.

f. Conclusions

The lethal area from Livens, with a 50/50 mixture of phosgene and chlorpicrin is 180 feet.

Dogs showed symptoms of phosgene only, 60 and 80 feet to the left, and 160 feet to the right of the projectile.

(32). C.C.P. 2.

Report of firing trial of 60 pdr. cast iron shell filled with phosgene and chlorpicrin.

Animals used, cats and goats.

a. Object

To show the marked results which can be obtained from a few well placed shell, filled with P.G., at low temperature ( $27.5^{\circ}\text{F}$ ).  
(The shooting in this trial was the worst ever witnessed at Porton).

b. Method

Time - December 19, 1917 - 3:30 P.M.

Artillery Data

Map range - 1750 yards. Front engaged - 40 yards.  
Effective area - 40x30 yards. No. rounds - 32.  
No. rounds in effective area - 7.  
Direction of fire - frontal.  
Accuracy - very poor. Time to fire all rounds - 9 Minutes.  
Rate of fire B.F. 15 seconds.

No. of experiment - 12

No. of howitzer 5" used - 3

Type of shell - G.I., R.L. design 25348A (1) with side filling hole and steel container to R.L.D. 3534 as used in steel shell.

C Type number - 0 374.

Bursting charge - C (b)

Propellant charge - 1st

Fuse - 106.

Blind shell - 0.

c. Meteorological Data

Barometer - 29.96 inches

Thermometer, wet bulb,  $26.5^{\circ}\text{F}$ .  
dry "  $27.5^{\circ}\text{F}$ .,  
ground  $22^{\circ}\text{F}$ .

Wind - N.E., velocity - 3 miles per hour

Sky - blue, cloudy

Rainfall - none during experiment, none during previous 24 hours.

#### d. Field Results.

### Concentrations of Phosgene & Chlorplorin.

Position	Time after burst of 1st shell			Concentrations			
	when sample was taken	above floor of trench at which sample was taken	Secs.	Mins.	Phosgene Mg./l.	Vol. of air cont. Vol. of air N.T.P.	Chlorpicrin Mg./l.
2	1	45	4	0	0.18	34,800	0.15
7	"	"	"	"	0.14	52,300	0.29
8	"	"	1	8	trace	-	0.45
12	"	"	4	0	0.15	30,200	0.69
15	"	"	"	"	0.39	11,600	0.73
18	"	"	1	8	nil.	-	0.14
19	"	"	4	0	trace	-	0.70
26	"	"	"	"	0.09	50,300	0.10
27	"	"	1	8	0.08	56,600	0.09
4	30	4	0	0	0.12	57,700	0.09
9	"	"	"	"	0.25	18,100	0.56
11	"	"	1	8	0.11	41,200	0.09
15	"	"	4	0	trace	-	0.62
17	"	"	"	"	1.14	3,940	0.82
22	"	"	"	"	nil.	-	0.20
24	"	"	1	8	nil.	-	0.14
27	"	"	4	0	nil.	-	trace
1	6	30	1	8	0.13	34,800	0.50
5	"	"	4	0	0.40	11,500	0.26
6	"	"	1	8	nil.	-	0.18
10	"	"	4	0	trace	-	0.09
14	"	"	"	"	nil.	-	0.09
23	"	"	8	1	nil.	-	0.25
28	"	"	1	8	0.64	7,070	0.10
28	"	"	4	0	0.26	17,400	1.04
1	9	40	"	"	nil.	-	7,060
3	"	"	1	8	nil.	-	0.80
6	"	"	4	0	trace	-	0.25
11	"	"	"	"	nil.	-	nil.
12	"	"	"	"	trace	-	-
20	"	"	"	"	0.08	56,600	0.18
21	"	"	1	8	0.16	28,300	0.44
25	"	"	4	0	0.29	15,600	0.78
29	"	"	1	8	0.64	7,070	0.65
Shelter		above floor					1.15
dugout 30	"	of dugout			0.11	41,800	1.03
Deep							6,380
dugout 31	"	"	"	"	nil.	-	7,150
Shelter							11,500
dugout 32	"	"	"	"	nil.	-	16,000

e. Toxicological Results

Position	No.	Died in:	Severe:	Light:	% Died:	% Severe:	Remarks
	Goats	48 hrs.	Class I				
Trench	7	1	5	1	14	86	10 of 4 goats 0 died
Dugout	1	0	0	1	0	0	1
In open at 50 yards	5	0	1	3	0	80	10 of 5 goats 0 died
In open at 75 yards	4	0	1	1	0	25	10 of 5 goats 0 died
In open at 100 yards	5	0	0	1	0	0	10 of 5 goats 0 died

Though no goats died, autopsy showed one at 75 yards was severe casualty, one in trench light casualty.

Goats were used instead of rats because of the extremely cold weather.

Observation on travel of the phosgene vapor. Cloud seemed very slight to observers 1100 yards from the artillery trenches and was quite invisible long before it reached them.

The probable direction of drift had previously been shown by means of a smoke candle and with 2 observers moving backwards and forwards at right angles to the wind direction, the points of maximum density were probably found.

In the field 1100 yards from trenches, phosgene and chlorpicrin could be detected by smell and smarting of the eyes, phosgene by smell, by paper test and by slight "tobacco" reaction noticed by one observer. This observer on moving 200 yards further away from trench, lost all trace of the clouds.

f. General Observations

Considering that only 7 shell fell in the effective area (one shell fell nearly on 50 yard line) it is remarkable that of 7 goats in the trenches, 1 was killed and 5 rendered severe casualties; that 1 out of 5 goats in the open at 50 yards from trench and 1 out of 4 goats in open at 75 yards from trench were also rendered severe casualties.

Average number of casualties in previous trials, 85% in this experiment, 86%.

g. Conclusion

Phosgene can be used effectively in cold weather.

33. C.C.P. 3.

Firing trial of 4.5" howitzer shell, container type,  
filled phosgene and chlorpicrin.

a. Method

Artillery Data

Front 20 yards, map range 1750 yards  
Effective area 20x30 yards  
Rounds in effective area 15.

b. Meteorological Data

Barometer - 30.07 inches  
Temperature, wet bulb - 41.5° F.  
dry " - 43° F.  
ground - 42° F.

Wind direction - S.E.  
" velocity - 7-8 miles per hour rising to 12 miles  
per hour.

Sky - overcast

Rainfall - none during experiment nor 24 hours previous.

c. Toxicological Results

Position of goats	No.: Dead	No.: Severe casualty	No.: Slight casualty	Remarks
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	:	:	:	:
In trench	:	4	:	0
In dugout	:	1	:	0
Open 50 yards	:	3	:	0
" 75 "	:	3	:	0
" 100 "	:	1	:	-

34. C.W.C. 95 - C.G.P. 6.

Tests with 4 inch Stokes filled with phosgene and chlorpicrin.

a. Method

Artillery Details

1 Stokes mortar. 41 four inch bombs with service bursters fired from

Trench front 20 yards at 340 yard range.

Time taken to fire all rounds 1 hour 20 minutes.

Direction of fire, enfilade. Accuracy, fair.

b. Meteorological Data

Ground temperature, 58° F.

in direction. Wind velocity, 1 miles per hour, drifts variable

General conditions, very favorable.

c. Toxicological Results

Position	No. of goats used	Dead in 48 hrs.	Severe casualties		Slight casualties	Percent-	Remarks
			Class a or b	Class C			
trench	8	8	0	0	0	0	9 rats 9 dead
dugout	1	1	0	0	0	100	1 " 1 "
In open at 50 yards	5	0	0	1	1	0	45 " 0 "
In open at 50 yards	3	0	0	0	0	0	0 "

Travel of cloud, 300 yards from trench, phosgene strongly in evidence before chlorpicrin was detected.

800 yards from trench, still observed 25 minutes after last bomb.

d. Observations

(1) Highest concentrations: phosgene 8.27 mg./l. chlorpicrin 8.40 mg./l.

(2) All animals in trench killed.

(3) Change in wind prevented gas from passing over animals in open.

35. Roberts, Clayton, Burrell, Oglesby.  
B.M. XXXVI-28.

Concentrations, toxicity and persistency of a mixture of chlорpicrin and phosgene fired statically from a Livens projectile in a trench. Filler: 5.94 cc. chlорpicrin (90.1% pure) and 5940 cc/  $\frac{1}{2}$  jpsgeme (98.1% pure).

a. Method

Artillery Data:

Time of firing - October 18, 1918 - 8:55 A.M.  
Quantity of load - 11,880 ccs.  
Booster charge - 6 ounces of black powder.  
Fragmentation - well opened.

b. Meteorological Data:

Wind velocity - under  $\frac{1}{2}$  miles per hour.  
Temperature of air - 53° F.  
Temperature of ground - 51° F.  
Weather: clear  
Relative humidity - 94 percent  
Barometric pressure - 29.88 inches.

c. Field Results:

Concentration Concentration in cc./l. over five-minute period.					
Phosgene			Chlorpicrin		
Max.	Min.	Avg.	Max.	Min.	Avg.
1.40	.00	.47	1.06	.00	.36
.00	.00	.00	.00	.00	.00
6.69	.07	1.91	6.49	.09	2.40
.08	.00	.01	.12	.06	.09
11.20	.45	4.19	3.98	.45	1.90
1.20	.00	.60	3.16	.57	1.06
7.38	3.18	5.70	5.22	2.25	3.62
8.46	1.05	5.02	10.26	3.08	5.88

d. Toxicological Results:

No dogs died as a result of exposure to this mixture.

e. Results

Toxic concentration obtained over a front of 180 feet. Thirty-five minutes after firing, the men lacrymated 100 feet to the right, and fifteen feet to the left of the drum. Phosgene was not detected. One hour after, the trench was untenable 200 feet to the left of the drum, due to the shift in wind direction and velocity. Two hours after firing, chlorpicrin was not noticeable 80 feet to the right. It was unbearable fifteen feet to the right. Twenty-four hours after firing, it was unbearable five feet to either side of the projectile.

## 36. C.W.C. 51, 55 &amp; 64.

Trial No.	S H E L L No.	Type	Bursting Charge	Range Yards	Front Engaged	Number Rounds of shoot	Duration fire	Direction of Wind vel.		Liters of miles per hour effective shell per yard front per mil.
								Min.	Sec.	
1	4	St.Ctr.	16 dr. tetryl	1750	40	50	4	32	frontal	4 .13
2	2	Cl MK I	5 dr."	1750	40	70	10	25	enfilade	.06
3	1	St.Ctr.	16dr."	1750	20	25	15	36	"	.06
4	4	St.Ctr.	Fumyl Ct(c)	1750	40	50	7	10	frontal	.11
55	2	St.Ctr.	"	1750	20	25	5	36	frontal	.10
6	2	St.Ctr.	"	1750	40	51	6	17	enfilade	.10
7	2	St.Ctr.	"	1750	40	50	7	9	frontal	.09
8	2	St.Ctr.	"	1750	40	50	6	36	frontal	.09

Note: With the exception of trial 5, in which the accuracy was "fair" all other trials were rated as "very good".

Trial No.	Number of goats used	Percentage killed	Percentage severe casualties including killed	
			Unclassified	
1	14	70		"
2	13	54		
3	7	100	100	
4	12	9	59	
5	7	0	85	
6	12	17	83	
7	10	80	100	
8	12	100	100	

## 37. G.C.P. 176.

with

Comparative firing trial of 6" M.I. howitzer shell filled  
 (a) Chlorpicrin 80% - Stannic Chloride 20%  
 (b) Phosgene - chlorpicrin

a. MethodArtillery Details

Shells	Chlorpicrin 80%	Phosgene-Chlorpicrin
	Stannic Chloride 20%	
Howitzer, 6"		
Number used:	1	1
Type	C.I.	C.I.
"G" Number of shells	0 1097	0 535
Bursting charge:	0 (e)	0 (e)
Propellant charge:	2nd Ballistite	2nd Ballistite
Fuse:	106 III	106 III
Blind shell:	0	0
Map range, in yards:	4050	4050
Target engaged in yards:	50x50	50x50
Rounds fired:	26	26
Rate of fire:	Time fired, 26 sec.	Gum fire 20 sec.
Time to fire all rounds:	11 minutes 22 seconds	9 minutes 42 seconds
Direction of fire:	frontal	frontal
Accuracy of shooting:	very good	very good

b. Meteorological Data

Wind velocity:	1 - 2 miles per hour
Direction of wind:	Mainly West
Temperature:	
Dry bulb:	66° F.
wet "	61° F.
Temperature of ground:	56° F.
Barometric pressure:	29.06 inches
Sky:	blue
Rainfall:	nil. during experiment and previous 24 hours.
General conditions:	Favorable
Time of day:	7:50 p.m.

c. Toxicological Results:

With chlorpicrin eighty percent - Stannic Chloride twenty percent.

Position	No.	Number	Percent	Percent	
	0. pigs	Killed	Passed	Normal killed	Killed & passed
On ground level	32	15	9	8	46
At 4 ft. level	17	6	6	5	35.3
Total	49	21	15	15	73

With phosgene and chlorpicrin

Position	No.	Number	Normal	Percent	Percent
	0. pigs	Killed	Passed	Killed	Killed & passed
On ground level	34	9	12	13	28.5
At 4 ft. level	16	4	8	9	25
Total	50	13	15	22	43.75

d. Results:

In a series of field tests which have been previously described, phosgene and chlorpicrin have proved their superiority over chlorpicrin 80% - stannic chloride 20%. The results of the above trial are distinctly in favor of the latter mixture, however. One such trial does not, however, prove that in 6" shells it is generally speaking more efficient than phosgene and chlorpicrin.

58. C.C.P. 205.

Experiments to determine the persistency of lethal gases in dugouts. Comparison of persistency of phosgene and chlorpicrin.

a. Method

Two 4" G.I. Stokes bombs, filled with PG. (a mixture of phosgene and chlorpicrin) and fitted with four grams ophorite boosters, and No. 8 detonator sleeves, with electric igniters were placed in a trench, one mid-way between the two entrances to a deep dugout, the other immediately opposite one of the entrances. Both bombs opened well and exploded simultaneously.

b. Meteorological Data

Wind velocity: 14 miles per hour.

Direction of wind: Northwest.

Temperature of air:

wet bulb - 42.5° F.

dry " - 44.6° F.

Temperature of ground - 43° F.

Sky - Overcast.

Rainfall - Nil. during experiment, .11 inch during previous 24 hours.

Barometric pressure - 29.15 inches.

c. Results

At 45 seconds after firing, the maximum of concentration of phosgene in the dugout was 1.53 mg./l. At 1 minute and 20 seconds, the maximum concentration of chlorpicrin in the dugout was 2.20 mg./l. At 10 minutes, chlorpicrin was not longer present in quantitative amounts. At 50 minutes the lachrymatory atmosphere in the trench and at both entrances to the dugout was noticed. In one hour and fifty minutes, an unprotected observer could just enter both shafts. In 3 hours 20 minutes, an unprotected observer went almost to the bottom of both shafts before he lachrymated. He experienced severe lachrymation in the main chamber of the dugout. In 5 hours, 20 minutes, the dugout and shafts were clear of chlorpicrin.

d. Conclusions

When 4" Stokes bombs, filled with B.G. burst in a trench near the entrance to a dugout, high concentrations of chlorpicrin may be produced in the dugout. The vapors of chlorpicrin persist in a dugout for a period of about six hours.

38. Kolls and Satler.  
P.T. VIII-A 398.

a. Object

To note the comparative effect of clouds containing cyanogen chloride and phosgene under the same field conditions.

b. Method:

Arrangement of field - see diagram in original report.  
8 Livens projectiles in a set fired simultaneously, moved to side of field just before firing due to change in direction of wind. Fragmentation good in all but one where there was a bad burst.

c. Meteorological Data:

Time of firing - 4:28 P.M.

On range near 2400 yard line.

Time - 4:30 P.M.

Temperature °F.

surface of ground - 41.6

altitude of 6 ft. - 43.0

Relative humidity % - 63

Barometric pressure, inches - 29.94

Wind direction from - North West

Wind velocity, miles per hr. at alt. 6 ft. - 4.3

Sky - overcast with low strata - cumulus clouds moving North West.

Ground - cool and moderately dry - no rains for 54 hours, slightly cooler than air above - gas clouds settled drifted along surface of ground.

d. Field Results:

Concentrations of phosgene and cyanogen chloride mixture in mg./l. total chlorine.

Distance : from origin	1	2	3	4	5	6	7	8	9	10	11	12
100 feet	3.83	4.11	33.6	1.76	43.8	6.01	2.37	none	0.33	none	2.54	0.15
300 "	1.48	2.11	0.02	0.06	none	lost	0.43	2.09	3.18	none	none	0.38
600 "	14.24	0.20	2.32	0.02	lost	4.55	0.15	0.14	0.006	none	none	3.41
900 "	1	-	1	-	1	-	1	-	1	-	1	-
100 feet	Time in seconds	-	14	24	34	and	54					
300 "	"	"	"	-	41	51	61	and	81			
600 "	"	"	"	-	82	92	102	and	122			
900 "	"	"	"									

Hand pump - average 0.112 for 10 minutes - began 123 seconds.

e. Results

Mixture of phosgene and cyanogen chloride gave no pronounced immediate effects of cyanogen chloride due to the small quantity. Small number of delayed deaths - little effect of phosgene due to small quantity.

See tabulations on page 174.

The cyanogen chloride in mixture did not produce pronounced effects. Symptom mild in 1st row, 2 dogs and 1 guinea pig died on field. All others showed signs of gassing. 2nd row - Severely gassed - 2 dogs died on field. Other rows - mild casualties.

f. Conclusions

A mixture of cyanogen chloride and phosgene is not as good as an equal amount of either gas alone, as determined by comparing the above test with tests of the pure gases.

40. C.C.P. 29. (3269)

Report on experiments to determine persistency of a mixture of phosgene and arsenic trichloride mark I after liberation from artillery shell. 4.5" howitzer shell, container type, filled with phosgene-arsenic trichloride mark I .358 cc.

a. Object

To determine under surface and over surface persistency of C.B.R. Mark I.

b. Method

Artillary Data:

Number of howitzers - 4; rounds fired - 100;  
Rate of fire - R.R. 5 sec, to 3 sec.;  
Time taken to fire all rounds - 8 minutes 30 seconds;  
Accuracy - good; rounds in effective area - 90;  
Type of shell & steel container; bursting charge - fumyl C(b);  
Propellant charge - 1st ballistite; fuse - #106;  
Blind shell - 3; Max range - 2300 yards;  
bombarded area 140 - 60 yards.

c. Meteorological Data:

Time	4900 P.M.	4:30 P.M.
Barometer, inches	30.10	30.10
Inermometer, wet bulb	57	54.6
dry "	38	35.3
ground	33	28
Wind direction	W	W-SW
velocity, miles per hour	4	3-5
Sky	blue	blue
Rainfall	nil during experiment and 24 hours previous	

d. Toxicological Data:

Observers unable to detect phosgene 4 to 6 minutes after. 5 guinea pigs exposed - no effect. 4 guinea pigs in, and one just to leeward of each crater.

e. Conclusion:

Under surface and over surface persistencies of phosgene negligible quantities. No samples taken for analysis.

(3348)

41. C.C.P. 219 (C.W.C. 59).

Report on firing trials of 4.5" cast iron howitzer shell  
filled phosgene and arsenic trichloride, Mark II.

a. Object

To test value of C.B.R. Mark II, as compared with C.B.R.  
Mark I.

b. Method

Auxiliary Details

	1	2	2	3
No. of 4.5" howitzers	2	2	2	3
Type of shell	steel	D.D.	cast iron	steel
	container		Mark X	container
Bursting charge	C (b)	D.D.(b)	C10(c)	C(b)HD(b)
				C10(a)
Max range, yards	1750	1750	1750	1750
Front engaged, yards	40	40	40	40
Effective area, yards	40x30	40x30	40x30	40x30
Rounds fired	55	52	56	55
Rounds in effective area	22	*	21	56
Rounds from range table	34	*	54	59
Rate of fire, B.F.	5 sec.	5 sec.	10 sec.	5 sec.
Time for to fire all rounds	5 min. 40 sec.	5 min.	8 min.	5 min.
		40 sec.	10 sec.	10 sec.
Direction of fire	frontal	enfilade	frontal	frontal
Accuracy of shooting	poor	poor	good	very good
G No. of shell	393	394	395	(393) (394) (395)
Propellant charge	1st Ballistite	1st	2nd	2nd
		Ballistite	Ballistite	Ballistite
Fuse	#106	106	106	106
Blind shell	0	0	0	0

\* Owing to frequent changes in wind directions and consequent alteration of  
line it is impossible to complete these details.

### Meteorological Data

	1	2	3	4
Data	Dec. 11, 1917	Dec. 23, 1917	Dec. 27, 1917	Jan. 3, 1918
Time of day	5:30 P.M.	5:15 P.M.	5:30 P.M.	5:45 P.M.
Barometer, inches	30.11	30.08	29.95	29.98
Thermometer wet bulb	53.	32.	33.	34.5
dry "	54.	33	34.	35.5
ground	28.	29.	31.	34.
Wind direction	N. E.	N.W. S. W.-W. N. W.	NNE	SW
velocity miles/hour	4	3-4	3-8	4-8
Sky	blue	blue-cloudy	blue-cloudy	overcast
Rainfall at test	nil	nil	nil	nil
Previous 24 hours	trace	nil	nil	trace

#### Toxicological Faculties.

### 1. Physiological Observational

No.	Position	No. of goats	Casualties			Percentages		Remarks
			Dead in use	Severe injury	Slight injury	Dead	Severe	
1	In trench	10	5	6	1	50	90	Of 11 rats, 10 died
	" dugout	1	0	1	0	0	100	1 rat which died
	" open at: 50 yards	5	0	0	4	0	0	Of 4 rats, 1 died
	at 100 "	5	0	0	5	0	0	" 5 " 0 "
2	In trench	7	4	2	1	57	86	Of 7 rats, 3 died
	" dugout	1	1	0	0	100	100	Of 1 rat, 1 died
	" open at: 50 yards	5	0	8	2	0	60	Of 2 rats, 2 died
	at 75 "	4	0	0	4	0	0	Of 4 rats, 4 died
	at 100 "	3	0	0	2	0	0	Of 2 rats, 2 died
	" 150 "	-	-	-	-	-	-	Of 3 rats, 0 died
3	In trench	6	0	2	3	0	50	Of 7 rats, 6 died
	" dugout	1	0	0	1	0	0	Of 1 rat, 0 died
	" open at: 50 yards	5	0	0	2	0	0	Of 5 rats, 2 died
	at 75 "	4	0	0	3	0	0	Of 4 rats, 1 died
	at 100 "	5	0	0	2	0	0	Of 5 rats, 0 died
	" 150 "	-	-	-	-	-	-	Of 3 rats, 0 died
4	In trench	7	5	1	1	71	86	Of 7 rats, 2 died
	" dugout	1	1	0	0	100	100	1 rat which survived
	" open at: 50 yards	5	1	0	3	20	20	Of 5 rats, 0 died
	at 75 "	4	0	1	2	0	25	Of 4 rats, 1 died
	" 100 "	3	0	0	2	0	0	Of 3 rats, 0 died

2. Observations on travel of clouds

- Exp. 1. 30 minutes after - 3500 yards from trenches.  
Exp. 2. 1700 yards - test paper turned.  
Exp. 3. 2500 yards - detected by odor and test paper.  
Exp. 4. 2500 yards - detected by odor and test paper  
(20 minutes after).

Experiment 1: Dense white cloud formed - spread S.E. at end of shoot. At 1200 yards - Sufficient phosgene present to turn test paper yellow - strong odor to lachrymation. At 1400 yards - Unprotected men coughed violently for 15-20 minutes.

Experiment 2: Opaque, dense cloud moved slowly from trenches, travelling S.E. - visible 5 minutes after shoot 1000 yards away. A pool of vapor, 40 yards in diameter seen in depression 500 yards east of trenches, an observer 12 minutes after end of shoot entered this pool. Sufficient phosgene present to irritate nostrils and gave taste for 2-3 hours. 2 observers at boundary of ground (1500 yards to 1700 yards) from trenches - distinct lachrymation - test paper turned yellow - tobacco reaction given. Cloud visible 20 minutes after shoot and up to at least 1000 yards beyond boundary fence.

Experiment 3: Cloud - S.W. direction - visible for distance of 300 yards. Limit for detection of phosgene 250 yards.

Experiment 4: Dense white cloud - moved north. Visible at 2500 yards for 2 observers, 2800 yards for third observer. At end of 20 minutes, not detected by odor just noticeable by test paper. Portion of cloud remained behind and hung stationary over ground. (1400 yards from trenches). At end of 26 minutes large quantities of phosgene present.

Concentration of phosgene (no attempt made to analyze the stannic chloride present but total chlorides were calculated as phosgene).

Position	Time after burst 1st shell when sample was taken		Height above floor of trench at which sample was taken	Concentration	
	Minutes	Seconds		Mg./liter	Volumes of air containing 1 vol.phosgene both at N.T.P.
5	1	0	4 0	1.06	4270
9	"	"	" "	.54	8380
11	"	"	" "	.57	7940
4	2	30	" "	5.71	753
8	"	"	" "	5.08	1470
14	"	"	" "	1.50	3020
18	"	"	1 8	.63	7190
5	4	30	4 0	3.04	1490
10	"	"	" "	4.25	1060
15	"	"	" "	.19	23800
6	"	"	1 8	45.01	98
12	"	"	" "	0.27	16800
1	5	15	4 0	0.48	9430
7	"	"	" "	0.92	4920
8	"	"	2 8	0.22	20600
16	"	"	" "	2.06	2200
dugout (above floor of dugout).					

#### e. Effects on Animals:

No. of trial	No. goats used	% Killed	% Severe casualties including killed
1	11	27	91
2	8	62	87
3	7	0	29
4	8	75	97

#### e. Comparison of C.B.R. II with C.B.R. I.

Concentrations obtained in case of C.B.R. II of same general order as average concentrations on all phosgene tests with 4.5" howitzers. As regards lethal properties of Mark I and Mark II - nothing to show which is more toxic. In former case 24 goats in all have been killed out of 60 used, in latter 13 out of 31 (40 and 42% respectively).

f. Conclusion:

No marked difference between efficiency of Mark I  
and Mark II.

Criticisms G.B.H. Mark I and Mark II are phosgene-  
arsenic trichloride mixtures.

42. C.O.P. M19. (1679)

Report on firing trial of 4.5" Howitzer shell, container type, filled - phosgene and arsenic trichloride.

a. Object

To determine number of shells filled C.B.R. required in a given front.

b. Comparison of 3 Experiments.

Date	May 8, 1917	Mar. 1, 1917	Mar. 1, 1917
Time of day	5:40 P.M.	10:30 A.M.	5:00 P.M.
No. and type of guns used	3-4.5" hows.	3-4.5" hows.	3-4.5" hows.
Type of shell	steel container	steel cont'r.	steel cont'r.
Map range, yards	1750	1750	1750
Front engaged, yards	40	40	40
Effective area, yards	40 by 30	40 by 30	40 by 30
Rounds fired	50	50	50
Rounds in effective area	29	30	26

c. Comparison of 6 Tests.		1	2	3	4	5	6
No. of experiment		Feb. 21, 1917	Feb. 21, 1917	Feb. 21, 1917	Mar. 1, 1917	Mar. 1, 1917	Mar. 1, 1917
Date					10:30 P.M.	3 P.M.	3 P.M.
Time of day		1 P.M.	6 P.M.	4 P.M.			
Barometer, inches		29.60	29.67	29.85	29.95	29.91	29.91
Thermometer, wet bulb °F.	45.	45.1	43.4	40.8	41.6	41.6	
" dry " "	45.	47.2	44.	43.	43.7	43.7	
Wind direction	S.E.-N	E.-N.-E.	W.-S.-W.	N.-E.-W.	E.-E.	—	
" velocity miles per hour	2-4	1-2	9-10	3	2	nil	
Sky	overcast	overcast	overcast	overcast	overcast	overcast	
Rainfall	nil	nil	nil	nil	nil	nil	
" previous 24 hours	0.12"	0.12"	0.11"	trace	trace	trace	
<u>Artillery Observations</u>							
Type of shell container	steel	steel	steel	steel	steel	steel	
No. of 4.5" how.	3	3	3	3	3	3	
Map range, yards	1750	1750	1750	1750	1750	1750	
Front engaged, yards	20	20	20	40	40	40	
Size of effective area, yds.	20x30	20x30	20x30	40x30	40x30	40x30	
No. of rounds fired	25	25	50	50	75	50	
Rounds in area	13	9	23	30	43	25	
Rate of fire B.F.	6 sec.	6 sec.	6 sec.	5 sec.	5 sec.	5 sec.	
Total time to fire	—	2 min.55 sec.	8 min.35 sec.	7 min.2 sec.	—	5 min.30 sec.	
Accuracy of shooting	good	fair	poor	very good	good	good	
Goats used	10	9	—	7	10	4	
No. dead in 48 hours	3	3	—	2	7	4	
Rabbits used	9	5	14	7	10	9	
No. dead in 48 hours	3	1	1	1	2	9	
Rats used; died 48 hours	6/7	4/5	—	4/7	—	2/2	
Mice " ; " " "	—	—	—	7/7	9/9	7/7	
% died, all animals	53.8	44.4	7.1	50.0	62.1	100	

Remarks: Trial No. 3 wind too high - trial no. 6 conditions ideal.

Rate of fire	3 sec.	5 sec.	5 sec.
Time taken to fire all rounds	6 min. 2 sec.	7 min. 2 sec.	5 min. 30 sec.
Wind velocity, miles per hr.	7-15	5	inappreciable
Animals killed, percent	0	50	100
Liters of liquid from effect- ive shell per yard of front per minute	0.11	0.1	0.11

4. Conclusions:

Experiment 1 compared with 2 and 3, shows that with a wind varying between 7 and 16 miles per hour no effect is likely to be produced.

In experiment 1, 12 goats were placed in the trench at about 5 yard intervals, but none were killed, 2 where direct hits were made were effected, 1 having severe respiratory distress for 4 days.

43. Kuhn, Richter, Lovenhart, Burrell, Clayton, Webster.  
B.I. INVII-89.

Preliminary pharmacological report on field test. Mustard Gas and Asmixtures. Test made August 21, 1918.

a. Object

Toxicity on dogs of pure mustard gas, crude mustard gas, pure mustard gas plus 15% phosgene, and pure mustard gas plus 15% chlorbenzol, when exploded from 75-mm shells.

Purity of pure mustard - 96.00%; or crude mustard 86.75%.

b. Method

Four fields used - fields lying perpendicular to wind direction.

Thirty-four 75 mm gas shells in each group; 6 rows of 4 shells each; rows 40 feet long and 4 feet apart--shell banks 180 feet apart. Each group fired in banks of 4 shell each. Shell laid on ground with their noses inclined slightly downward. Interval between firing of each group - 10 seconds.

Animals - 20 dogs in front of each shell bank; 5 rows, 4 dogs each--each row 60 feet long, 13.7 ft apart--dogs fastened by 3-ft. chains. Front row-20 feet from front line of shell. Rear row-75 feet from front line of shell.

Period of exposure - 10 A.M. to 1 P.M.

All shell filled to 7/8 vol. (415 cc.) - fitted with regular Marx IV loaded boosters and adaptors.

c. Meteorological Data

Weather - clear, warm sun

Wind -  $\frac{1}{4}$  miles per hour at firing, ave. 6 mi./hr. for 1 hr.

Temp. - Air 81°F., ground 89°F., wet bulb 69°F.

Relative humidity - 54%.

Pressure - 30.08 inches.

Sampling intervals - 1, 2, 3, 4, 5 min. from front row to back.

d. Analytical Data

Mg. per liter total chlorides.

Pure Mustard			Crude Mustard			Pure mustard & 15% phosgene			Pure mustard & 15% chlorbenzene		
a	b	c	a	b	c	a	b	c	a	b	c
.10	.12	.12	.12	.08	.11	.18	.28	.14	.13	.11	.11
.08	.09	.27	.12	.12	.09	.47	.12	.14	.11	.09	.07
.11	.07	.06	.15	.16	---	.10	.14	.16	.12	.15	.12
.06	.08	.09	.06	.06	.13	.11	.09	.07	.16	.00	.09
.08	.06	.06	.10	.37	.08	.10	.12	.07	.13	.12	.10

Fragmentation -

Pure mustard - 6 poor, 18 good

Crude mustard - 5 failed, 11 poor, 8 good

Mustard plus 15% phosgene - 2 failed, 14 poor, 8 good

Mustard plus 15% chlorbenzene - 13 poor, 11 good

e. Results

Pure mustard gas plus 15% phosgene.

Died 69 hours	Died 21 hours	Died 18 hours	Died 22 hours
Died 95 "	Died 21 "	Died 54 "	-----
Died 46 "	Escaped	Died 8 days	-----
Died 45 "	Died 8-1/2 days	Died 26 "	-----
Died 7 days	-----	-----	Died 19 days

f. Summary

1. To date the mortality on each group is:
 

pure mustard plus phosgene	-	70%
Pure mustard	-	55%
Pure mustard plus chlorbenzene	-	30%
Crude mustard	-	40%
2. During exposure animals exposed to mustard and phosgene were more depressed than those of other groups.
3. A mixture groups showing earliest deaths - rank
  - 1st. Phosgene and mustard, 5 deaths in 48 hours.
  - 2nd. Chlorbenzene and mustard, 3 deaths in 48 hours.
  - 3rd. Crude mustard, 1 death in 48 hours.
  - 4th. Pure mustard, no deaths in 48 hours.
4. Low mortality with crude mustard partly due to poor fragmentation.

44. Kuhn and Kolls.  
P.T. VIII-A397.

a. Object.

Comparison of the toxicity of (1) pure mustard, (2) crude mustard, (3) pure mustard containing 15% of phosgene and (4) pure mustard containing 15% chlorbenzene, when used as fillers in 75 mm. shell fired statioally under field conditions, Sept. 16, 1918.

b. Method.

1. Shell banks - 24 shell each, line perpendicular to wind - 180 feet apart.

2. Shell fillings - 7/8 vol. - 415 cu. cm. of filled. Mark IV booster - 50 gms. T.N.T., 10 gms. tetryl.

Field A - pure mustard with 15% chlorbenzene  
" B - pure mustard with 15% phosgene  
" C - crude mustard (63% pure)  
" D - pure mustard (96.25% pure)

3. Location of shell.

- (a) 24 shell in each field.
- (b) 6 rows, 4 shell each.
- (c) Distance of rows - 4 ft. apart from each group 40 feet
- (d) Position of shell - nose inclined slightly downward
- (e) Order of firing - each group fired banks of 4 shell at 10 sec. intervals; corresponding banks in each group were fired simultaneously.

4. Location of animals:

20 dogs in front of each group of shell - 5 rows, 4 dogs in each row, rows 13 $\frac{1}{2}$  ft. apart, distance from lime or shell to front row 20 ft., rear row 75 ft.

5. Exposure:

- (a) Toxicity test - 11:15 A.M. to 3:15 P.M.
- (b) Persistence, in positions 1 and 4, of the first row 4:30 P.M. to 10:30 P.M.
- (c) Persistence, in positions 2 and 3 of the first row 23 hrs. after firing - 10:15 A.M. to 4:15 P.M.

#### 3. Meteorological Data

Weather - mild, warm day, light clouds  
Wind - 5.1 miles per hour at time of firing

5.8 miles per hour, ave. velocity for 1 hr. after  
firing

Temperature - air - 79° F.

ground - 80.6° F.

wet bulb - 68.2° F.

Relative Humidity - 58%

Pressure - 29.87 inches

Direction of Wind -

Time of firing - right angles to field

10 min. later - veered to left

during first hour - varied between right angles and  
left inclination.

Probably accounts for more deaths in left of field.

#### 4. Toxicological Data

##### (1) Field B - Pure mustard and phosgene.

Dead 111 hrs.	Dead 220 hrs.	Dead 25 days	Dead 16 days	Dead 25 days	Escaped
Dead 100 "	Dead 206 "	Dead 211 hrs.	Dead 25 days	Dead 252 hrs.	-----
Dead 15 "	Dead 200 hrs.	Dead 252 hrs.	Dead 41 hrs.	-----	-----
Dead 56 "	Dead 8 hrs.	Dead 41 hrs.	-----	-----	-----

##### Shell

How	1	2	3	4	5
No. died	3	3	3	3	1
No. killed for autopsy	1 (31 days)	1	0	1	

##### (2) Field B - Persistence Test.

Length of exposure, hours	6	6	6	6
Time after firing shell, hours	6	6	23	23
Position of dogs	1-1	1-4	1-2	1-3

##### (3) Total Number Casualties.

Pure mustard and phosgene - 13 deaths, 2 sev. 4 light casualties  
" " " chlorbenzene - 15 ", 3 " 2 " "  
Grade " - 15 deaths, 5 light casualties  
Pure mustard - 12 deaths, 1 severe, 5 light casualties

##### (4) Time of death.

Crude and pure mustard, earlier deaths than produced  
by admixtures.

Time of death within	Pure mustard chlorbenzene	Pure mustard phosgene	Crude Mustard	Pure Mustard
48 hours	5	5	5	4
72 "	8	8	9	8
144 "	5	5	11	9
288 "	12	11	15	11
3 weeks	15	11	14	12

e. Conclusions:

1. From standpoint of toxicity.

- (a) Little difference between crude mustard and pure mustard and chlorbenzene.
- (b) Little difference between pure mustard and pure mustard and phosgene.
- (c) Crude mustard predominates slightly over pure mustard.

2. From total number casualties - rank

- 1st. Pure mustard plus 15% chlorbenzene
- 2nd. Crude mustard
- 3rd. Pure mustard plus 15% phosgene
- 4th. Pure mustard

3. From standpoint of persistence

- (a) Six hours after firing of shells - rank
  - 1st. Pure mustard plus 15% chlorbenzene
  - 2nd. Crude mustard
  - 3rd. Pure mustard plus 15% phosgene
  - 4th. Pure mustard.
- (b) Twenty-three hours after firing of shell - rank
  - 1st. Chlorbenzene admixture
  - 2nd. Crude mustard
  - 3rd. Pure mustard
  - 4th. Phosgene admixture (rapid drop in concentration).

45. Kolls and Kuhn.  
B.M. XXVIII-90.

Toxicity on dogs of 50% carbon monoxide and 50% phosgene.

a. Object.

To determine effects on dogs of a cloud consisting of 50/50 mixture carbon monoxide and phosgene from cylinders.

b. Method.

50 lb. mixture of gas from each of 2 cylinders - 20 feet apart.

Length of exposure - 30 min. (actually exposed to gas about 2 minutes. H.A.K.)

Position of dogs:

1. Five dogs, 20 ft. intervals, 40 ft. from cylinders
2. Seven dogs, 20 ft. " ,100 " " "
3. Six dogs, 50 ft. " ,200 " " "

c. Discussion:

1. Time for complete discharge of cylinders  
(a) Left - 1 min. (b) Right - 2 min.
2. Wind  
(a) Direction - right angles to field  
(b) Velocity - 7 to 8 miles per hour.

d. Results.

1. First row:  
All showed depression, conjunctivitis, lachrymation, dyspnoea.

Center dog and one left of center:  
(a) immediate vomiting  
(b) death within 24 hours.

2. Second row:  
Five central dogs: lachrymation, slight dyspnoea, depression.

End dogs unaffected.

All normal in 48 hours.

3. Third row:  
Three central dogs: lachrymation  
End dogs: unaffected  
All normal in 48 hours.

e. Conclusions

1. Effect of mixture less than equal amount of either arsine or phosgene on dogs under similar conditions.

2. Area of lethal concentration.

40 feet from cylinders along center line  
20 feet to left.

46. Richter, Bruce, Smith, Loevenhart and Kolls.  
S.M. XXX-76.

a. Object

To determine toxicity of a 50-50 mixture of phosgene and chlorine when used in the mobile gas unit, under field conditions.

b. Methods and Details

Two cylinders, 30 lbs. each, of the mixture used. Animals and cylinders arranged as in diagram in original report. Time of exposure 30 minutes.

Amount of gas discharged from cylinder I - 30 lbs.

" " " " " II - 50 "

Time of discharge from cylinder I - 55 seconds complete

" " " " " II - 55 seconds with nozzle,  
20 seconds without

Note: Approximately .75% of total amount of toxic material was discharged in the 55 second period.

c. Meteorological Data:

Wind - 7 - 8 miles per hour.

Temperature of air - 61°F.

" " ground - 58.4°F.

Barometer - 29.75 inches

Relative humidity - 42.5%

Clear, bright sunshine.

d. Field Results:

Time	Sample No.	Concentration Wt./l.	
		Total Chlorine	Free Chlorine
4 sec.	A. 1	0.25	0.00
10 "	2	0.07	
30 "	3 a	—	0.00
30 "	3 b	0.10	
1 min.	4	0.00	
2 "	5	stopcock leaked	
4 sec.	B. 1	12.70	
10 "	2	3.52	
30 "	3 a	—	0.09
30 "	3 b	1.55	
1 min.	4	4.57	
2 "	5	0.92	

Time	Sample No.	Concentration, Mg./l.	
		Total Chlorine	Free Chlorine
4 sec.	C. 1	0.16	
10 "	2	2.89	
30 "	3 a	—	5.07
30 "	3 b	6.68	
1 min.	4	0.55	
2 "	5	0.26	
4 sec.	D. 1	0.60	
10 "	2	0.48	
30 "	3 a	—	0.00
30 "	3 b	0.00	
1 min.	4	0.00	
2 "	5	0.34	
4 sec.	E. 1	0.54	
10 "	2	0.10	
30 "	3 a	—	0.00
30 "	3 b	0.00	
1 min.	4	0.00	
2 "	5	0.25	
4 sec.	F. 1	0.57	
10 "	2	0.26	
30 "	3 a	—	0.06
30 "	3 b	0.59	
1 min.	4	0.76	
2 "	5	0.90	
4 sec.	G. 1	0.10	
10 "	2	0.10	
30 "	3 a	—	0.00
30 "	3 b	0.54	
1 min.	4	0.24	
2 "	5	0.54	
4 sec.	H. 1	0.90	
10 "	2	0.00	
30 "	3 a	—	0.00
30 "	3 b	0.00	
1 min.	4	0.09	
2 "	5	0.01	
4 sec.	I. 1	0.01	
10 "	2	0.09	
30 "	3 a	—	0.00
30 "	3 b	0.01	
1 min.	4	0.30	
2 "	5	0.00	

Time	Sample No.	Concentration M.E./l.	
		Total chlorine	Fresh chlorine
4 sec.	J. 1	0.26	
10 "	2	0.22	
30 "	3 a	---	0.00
30 "	3 b	0.00	
1 min.	4	0.30	
2 "	5	0.00	
4 sec.	K. 1	0.00	
10 "	2	0.00	
30 "	3 a	---	0.00
30 "	3 b	0.05	
1 min.	4	0.97	
2 "	5	0.10	

e. Toxicological Results

Dogs exposed for 30 minutes -

All dogs in 1st row showed depression, conjunctivitis, lachrymation, dyspnoea. 2 dogs vomited.

Five dogs in center showed lachrymation, slight dyspnoea, and depression. Dog on either end of row unaffected.

In third row, dog to left of center and 2 dogs to right of center showed lachrymation. Other dogs unaffected.

In 24 hours dog in center of 1st row - dead.

In 24 hours dog to left of center of 1st row - dead.

In 24 hours other dogs center of 1st row - depressed, recovered in 48 hrs.

In 24 hours all dogs in 2nd row - normal in 48 hours.

f. Conclusions

Lethal concentration for dogs was produced in 1st row from center dog to dog 20 feet to left of center.

All dogs in 1st row (20 ft.) incapacitated.

Effect of mixture much less than an equal amount of arsine or phosphorus discharge under similar conditions in same position.

47. C.C.P. 242. (3965)

Phosgene, arsenious chloride, chlorpicrin and stannic chloride.

Summary of maximum persistencies for various chemical fillings in shell, bombs and dryers.

Filling	Over surface	Under surface	Covered Sur-	Travel of cloud
Phosgene	i 15 min. in water, Livens:	: Mil. G.C.P. 3423	: 14-5 hrs., 2-4 Stokes, also : 1800-2250 yards	
	: drum	:	: 2-2" R.M. bombs	: 50-4.5" how.
	: G.C.P. 3326	:	: exploded in	: shell
	:	:	: trench	: G.C.P. 3570
	ii	:	: G.C.P. 3423	:
Phosgene and chlorpicrin	: 2-5 hrs. ob- servers erect	: 100 hours	: 6 hrs. 2-4" Stokes bombs	: 2000 yds. at
	: 10-22 hrs. ob- servers stoop-	: G.C.P. 2640	: trench	: 2000 yds. severe
	: ring G.C.P. 2649:	:	: G.C.P. 5125	: lacrimation from
	: 10-12 hrs. ob-	:	: 16 hrs. 50-4.5" shells	: 50-4.5" howitzer
	:	:	: Howitzer shell	: G.C.P. 2639
Phosgene	: mil.	: mil.	: 30 min. minimum	: 3500 yds. traces
arsenious cl. and phosgene:	: G.C.P. 3269	: G.C.P. 3269	: 2-4.5" how's.	: of phosgene de-
stannic cl. :	:	:	: exploded in	: tected, very
:	:	:	: trench	: marked at 1400
:	:	:	: G.C.P. 3938	: yds., 50-4.5"
:	:	:	:	: how. shell
				: G.C.P. 3348

XIV. BIBLIOGRAPHY.

Effect on Animals.

B.H.	P.T.	O.O.P.	O.W.C.
I-29	VIII-A385	42	50
VII-50	VIII-A386	74	67
XIV-63-1	VIII-A386	107	78
XII-74	VIII-A389	108	110
XXI-76	VIII-A393	178	
XXXX-138		205	
XXVIII-90-8		215	
XXIX-75		221 (3770)	
XXXII-57		228	
		361	

Effect on Mammal.

Ph. 1, 4, 13, 17, 20, 21, 40, 53

B.H. IX-35

A.E.F. 66, 48-0-5

C.C.P. 148 (6064)

H.B.D. 5

P.R. Ver220

A.P.M. 34-9-No. 7

Effect on Animals and Mammal.

B.H.	P.T.	O.O.P.	O.W.C.	A.E.P.	C.L.	A.G.	Z.	P.S.
XVII-84-	VII-A348	2	51	176	18	21	83-A	XLIV-II-23
12-39	VIII-A351	3	54				550	XXXIX-39
XVIII-90-	VIII-353	6	55				607	
10	VIII-A355	29	64					
XIX-76	VIII-A387	175	77					
XXIV-56	VIII-A390	217	89					
XXVI-28	VIII-A398	219	95					
		342						

Field Tests (Phosgene Alone).

B.M.	P.T.	H	I	HeDoDo	
XXVI I-48	II-A127	1	30-2	3	J.H.M. 33
XXVI II-90	VIII-A385	2	30-11	45	C.W.M. XII-part II
XXXI-75	VIII-A386	36	30-12	46	H.A.C.D. 101
XXX-63	VIII-A388	37	30-34	50	M. Ph. 26 and 29
XXX-64	VIII-A389	40	30-39		
XXX-66		44	30-44		
XXXI-78		46	275		
XXXI I-93		53			
XXXV-60		64			
		75			
		87			
		97			
		98			
		114-499			
		115			
		120			
		124			

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DEPARTMENT OF THE ARMY  
US ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND  
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REPLY TO  
ATTENTION OF

RDCB-DPC-RS

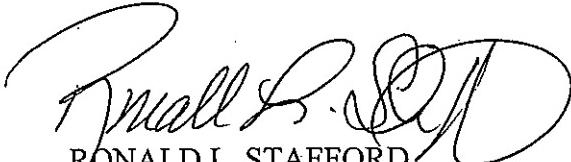
15 October 2015

MEMORANDUM THRU Director, Edgewood Chemical Biological Center, (RDCB-D/Dr. Joseph Corriveau), 5183 Blackhawk Road, Aberdeen Proving Ground, Maryland 21010-5424

FOR Defense Technical Information Center, 8725 John J. Kingman Road, Ft Belvoir, VA 22060

SUBJECT: Internal Request for Change in Distribution

1. This action is in response to an Edgewood Chemical Biological Center (ECBC) Internal Request for a Change in Distribution for the following documents as listed in attachment.
2. The listed documents have been reviewed by ECBC Subject Matter Experts and deemed suitable for the change in distribution to read "Approved for public release; distribution unlimited."
3. The point of contact is Adana Eilo, ECBC Security Specialist, (410) 436-2063 or [adana.l.eilo.civ@mail.mil](mailto:adana.l.eilo.civ@mail.mil).

  
RONALD L. STAFFORD  
Security Manager

Encl

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